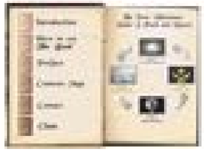
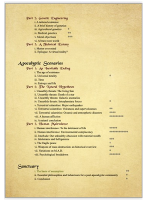
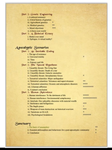




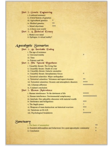
Apocalyptic Scenarios

Sub-chapter	Section	Subject Matter	People
Part 1: An Inevitable Ending	*i. The age of existence*	Determining the age of the Earth: a short history (from religious cosmology to radiocarbon dating) ● The Earth, the Moon, & the Sun: our place in a 13.8 billion-year-old universe ● The importance of rigid scientific enquiry & the dangers of pseudoscientific alternatives to reality ●	**Mikhail Lomonosov | George-Louis Leclerc | William Smith | James Hutton | Charles Lyell | William Thomson | Thomas H. Huxley | Hermann von Helmholtz | George Darwin | Ernest Rutherford | Bertram B. Boltwood | Arthur Holmes | Clair Cameron Patterson**
	ii. Universal totality	Our scientific understanding of the cosmos: from its size & age to its birth & death Investigating the Big Bang & the formation of our four-dimensional world (from a quark-gluon plasma to galactic superclusters) ● Defining the '*Planck temperature*' & visualising the outward expansion of the universe ● 'Dark matter' & 'dark energy' (in layman's terms) ● Alternative models of cosmological expansion	**Albert Einstein | Neils Bohr | Steven Weinberg | Stephen Hawking | Roger Penrose | Georges Lemaître | George Gamow | Arno Penzias | Robert Wilson | Robert Dicke | David Wilkinson | George Smoot | John Mather | Fred Hoyle | Richard A. Muller | Saul Perlmutter | Eric Chaisson | Alan Guth | Robert Caldwell | Hugh Everett**

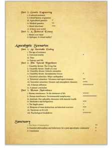


Part 1: An Inevitable Ending *(...continued)*	*iii. Time*	Time as a prerequisite of all physical existence: measuring the passing of time ● '*Planck time*' & the importance of *photo-equilibrium* ● Visualising time as a *quantised* dimension (from the Big Bang to the present moment) ● The hastening of time & retreat of the '*Hubble perimeter*' (supporting the '*Big Rip*' hypothesis) ● Our perceptual confusion of space & time ● Perceiving our finite existence	**Albert Einstein**
	iv. Entropy and life	The apparent contraflow of entropy through living reproduction ● Our ultimate inability to countenance the hastening march of time & universal dissipation of energy	**Ilya Prigogine | Albert Lehninger**
Part 2: The Natural Hypotheses	*i.* ***Unearthly threats****: The living Sun*	The composition, temperature & activity of the Sun ● A short history of terrestrial solar observation (from '*Galileo*' to '*NOAA*') ● The ever-present dangers of coronal mass ejections & a historical correlation with solar activity ● Investigating *sunspots* & recent solar cycles ● '***NORAD***' and the susceptibility of satellites & defence systems ● Understanding our star: space-based observations (from '*Solar Max*' to the '*Parker Solar Probe*')	**Galileo Galilei | Samuel Heinrich Schwabe | Joseph von Fraunhofer | Robert Bunsen | Gustav Kirchhoff | Richard Carrington | George Ellery Hale**
	ii. ***Unearthly threats****: Death of a star*	How our Sun will eventually die (from *red giant* to *white dwarf*) ● Examining supernovae & the different types ● Historic supernovae (from the '*Crab Nebula*' to '*SN2006gy*' ● Candidates for future supernova events in the Milky Way (from '*Rho Cassiopeiae*' to '*IK Pegasi*') ● Extra-galactic explosions (*magnetars* & *quake novae*)	**Wolfgang Schuler | Francesco Maurolico | Tycho Brahe | Johannes Kepler | Edmond Halley**
	iii. ***Unearthly threats****: Galactic anomalies*	Our place in the galaxy (velocity & comparable size) ● The threats of nearby stars & the theorised existence of '*Nemesis*' ● Cosmic upheavals: the '*Local Bubble*', *local fluff* & '*Smith's Cloud*' ● The likely consequences of our galactic collision with Andromeda	

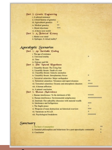
Part 2: The Natural Hypotheses *(...continued)*	*iv.* ***Unearthly threats****: Interplanetary forces*	The Moon & its stabilising effect ● The decline of Phobos (Mars' innermost moon) ● Exploring the asteroid belt & the *NEOs* within (the *Amors, Apollos & Atens)* ● From '*1036 Ganymed'* to *'1950DA'*) ● Fireballs & meteoroids ● The *Trojans* & the *Hildas* ● Planetoids of the Kuiper Belt ● Residents of the *scattered disc* (from '*Sedna*' to '*Leleākūhonua*') ● The Oort Cloud & the historical significance of comets (from '*Kirsch's Comet'* to *'Shoemaker -Levy 9'*) ✽ Asteroids & comets: a growing awareness of their dangers & the mixed blessings of Jupiter ● Examining craters & extinction pulses ● The effects of historic encounters (from the European *dark ages* to reducing biodiversity) ● Detecting near-Earth objects: ('*NEAT*' & '*LINEAR*') ● Missions to study specific asteroids & comets (from '*Hayabusa'* to *'Osiris-Rex*') ● Lacking foresight & the future of '*Apophis*'	**Isaac Newton | Edmond Halley** ✽
Part 2: The Natural Hypotheses *(...continued)*	*Footnote*	A note on commercial & private space ventures	
Part 2: The Natural Hypotheses *(...continued)*	*v.* ***Terrestrial calamities****: Major earthquakes*	The importance of continental drift & the process of plate tectonics ● The composition of Earth's interior (from inner core to lithosphere) ● Basalt & granite: the interactions between oceanic & continental crusts (from the *Ring of Fire* to the *Great Rift Valley*) ● Investigating earthquakes: seismic shockwaves & the *Mohorovičić discontinuity* ● Measuring earthquakes & understanding their numerous hazards (from *soil liquefaction* to *tsunamis*) ● Historic earthquakes (from the '*Great Alaskan Earthquake'* of 1964 to the '*Great Sumatran-Andaman Earthquake*' of 2004	**Voltaire | Jean Jacques Rousseau | Immanuel Kant**



Part 2: The Natural Hypotheses *(...continued)*	*vi.* ***Terrestrial calamities****:* *Volcanoes and supervolcanoes*	Explaining volcanoes: different formations, lava types & common hazards (from *pyroclastic flows* to *lahars*) ● The atmospheric impact of noxious volcanic gasses (from sulphate aerosols to hydrogen fluoride) ● Volcanic earthquakes & historic European eruptions (from '*Etna*' to '*Santorini*') ● Iconic volcanoes (from '*Fuji*' to '*Muana Loa*' ● Explaining the 'Volcanic Explosively Index' (*VEI*) & comparing historic examples (from '*Tambora*' to '*Pinatubo*') ✽ Definition & types of supervolcano (examples of today's active hotspots) ● Supervolcanoes & prehistoric extinctions: *flood basalt events* & *large igneous provinces* (from the '*Central Atlantic Magmatic Province*' to the '*Deccan Traps*') ● The calderas that belie mega-collosal events ● Supervolcanic eruptions since the evolution of humans ('*Lake Toba*' & '*Lake Taupo*') ● The '*Yellowstone hotspot*': a history of super volcanic eruptions, the ever-shifting topology of Yellowstone Park, & the likely consequences of a future eruption ● *Volcanic winters* & *anoxic events*: the oceanic & atmospheric devastation from a mega-collosal eruption
	vii. ***Terrestrial calamities****:* *Oceanic and atmospheric disasters*	Earth's atmosphere & the extent of the biosphere ● A brief look at Earth's hydrosphere & its important role in sustaining life ● The Sargasso Sea, journey of the Gulf Stream & the North Atlantic Drift ● Life in the photic zone: a fragile existence ● Megatsunamis ✽ Glaciation & post-extinction periods ● Prehistoric ice ages: from the Cryogenian period to the present ● The Quaternary ice age & the rise of the hominids (forcing the intellectual evolution of our species) ● CO_2 levels & the dangers of anthropogenic emissions (from the collapse of the ice shelves to the unstoppable retreat of the cryosphere ✽



Part 2: The Natural Hypotheses *(...continued)*	*vii.* ***Terrestrial calamities****:* *Oceanic and atmospheric disasters* *(...continued)*	Tropical cyclones & the ‘*Saffir-Simpson Hurricane Scale*’ ● Notable super-typhoons & the immensity of ‘*Typhoon Tip’* ● Major hurricanes & their cost to the US economy ● The deadliest tropical cyclones (from the ‘*1970 Bhola Cyclone’* to *‘Hurricane Mitch’)* ● The growing frequency of extra-tropical storms & weather extremes ❁ The ‘*ENSO*’ (*El Niño & La Niña*) & its place in the intricate system of oscillating ocean-atmosphere anomalies ● A look at prehistoric El Niño events & their increasing frequency and prominence in recent decades ● The environmental devastation & human suffering caused by strong El Niño events (in 1997-8 & 2014-16) ● Coastal wind shifts, the perturbation of vital currents & the creation of hypoxic conditions ❁ The eutrophication of coastal waters & the growing problem of *dead zones* ● The processes that lead to sea floor hypoxia ● Prehistoric dead zones & their correlation with atmospheric CO_2 levels ● Human activity & its effect on the natural solubility pump ● Rising ocean acidity & its effect on calcifying organisms ● The rising *lysocline* & its threat to the carbon cycle ● Oceanic destabilisation & the ‘*clathrate gun hypothesis*’: the catastrophic release of stored methane ● Anticipating the collapse of thermohaline circulation (oceanic ‘conveyor belts’ of energy & nutrients) as a prelude to an ‘*oceanic anoxic event’* ● An apocalyptic comparison with the ‘*Great Dying*’ (the Permian-Triassic mass extinction event)	
	viii. A human affliction	Definition of an apocalyptic scenario & the growing likelihood of a global apocalypse ● The fragility of a human civilisation based on knowledge & military force ● From scientific revolution to Western imperialism: the dominance of European powers in shaping modern	



Part 2: The Natural Hypotheses

(...continued)

viii. A human affliction

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civilisation ● Uniquely human tragedies: malnutrition & infectious disease in poorer nations / degenerative disease & hypertension in the developed world ● From drug misuse to road traffic accidents: the mundane afflictions of modern life

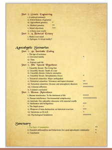
The day-to-day concerns of living existence: China as a microcosm of human suffering (the returning calamities of *flood, drought, famine* & *disease*) ● Industrialisation & economic growth: presenting a new set of hazards (from environmental mismanagement to the stability of food security)

Identifying apocalyptic scenarios as being primarily physical, chemical or biological in nature ● Implausible biological apocalypses (from mass-impotency to the '*weak-gened hypothesis'* & *'dysgenics*')

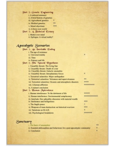
Human disease: the devastating power of pathogenic microbes ● The 'Black Death': the deadliest & most infamous pandemic in human history ● *Y. pestis* & an insight into the different types of plagues ('bubonic', 'septicaemic' & 'pneumonic') ● Discerning the three historical plague pandemics (the '*Plague of Justinian', the 'Black Death'* & the *'Third Pandemic*') ● Endemic outbreaks of plague in the modern world & the ongoing dangers of primary pneumonic plague

Justinian I

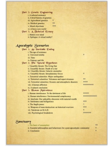
Smallpox: the greatest pathogenic killer ● *Variola major* & its historic



Part 2: The Natural Hypotheses *(...continued)*	*viii. A human affliction* *(...continued)*	impact on humanity ● The different types of smallpox & its eventual eradication ● Measles, malaria & tuberculosis ● The array of other debilitating diseases that continue to threaten human health (from cholera to leprosy)	
		The virology & epidemiology of influenza ● Antigenic shift & the history of '*Spanish flu'* ● The zoonotic potential of influenza: from the '*2009 swine flu pandemic*' to the potential dangers of *H5N1* avian flu	
		Diseases that result directly from human activity - SARS & COVID 19 ● CJD & the dangers of *prion* diseases (from scrapie to kuru) ● Antibiotics & their overuse as a farming supplement (the creation of drug-resistant strains of bacteria) ● *Superbugs*: MRSA, VRE & NDM1	
		AIDS: a short history & explanation of the disease (defining the types of HIV) ● The origins of HIV & debunking ill-conceived theories ● Highlighting the scale of devastation from the AIDS pandemic	
		Pathogenic microbes: virulence vs. contagion (an evolutionary 'rule of thumb') ● Ebola & Marburg: the deadliest '*viral hemorrhagic fevers*' ● The causative virus of VHF: from 'Rift Valley virus' to 'Lassa virus' (the persistent dangers of readily adaptable pathogens)	
		Pathogenic microbes, 'biological research establishments' & the continuous creation of novel strains ● The surreptitious testing of biological agents (from *'Biopreparat'* to *'Fort Detrick'*) ● Weaponising bacteria & viruses: the creation of deadly transgenic pathogens ● The insanity of pursuing aggressive biotechnology (from recreating historic pathogens to '*morphic resonance'*)	**Rupert Sheldrake**



Part 2: The Natural Hypotheses *(...continued)*	*ix. A natural conclusion*	The variety of natural disasters that could befall humanity & the likely collapse of modern civilisation ● The challenges we face as a species
Part 3: Human Malevolence	*i. **Human interference**: to the detriment of life*	Putting life into context (from prehistoric mass extinctions to the consequences of human activity) ● 'Anatomically modern humans' & the *Upper Palaeolithic Revolution* ● 'Clovis' culture & the extinction of American megafauna ❃ Delving into the unfolding *Holocene extinction event*: our devastating impression on the natural world & present rates of extinction ● Indicator species & the human irreverence of life: the deteriorating health of countless species of coral, amphibians & insects ● Pollution & the loss of bees and other insects essential to our own survival ❃ Exposing the magnitude of human destruction: killing the natural world & jeopardising our own existence ● The perfect ' switching predator': examples of how we impact the *web of life* ● An insight into the consequences of our wholesale destruction of the world's forests ● The unprecedented disasters of anthropogenic climate change, pollution, human overpopulation & loss of biodiversity (from 'persistent organic pollutants' to the introduction of alien species) ❃ Explaining the ***IUCN*** *'Red List*': '*least concern'* to *'extinct in the wild'* (from the common wood pigeon to the Socorro dove) ● Recently



Part 3: Human Malevolence

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i. ***Human interference****: to the detriment of life*

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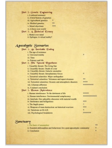
extinct animals & plants (from the thylacine to the St. Helena olive) ● The overwhelming tide of human expansion & the inadequacies of the ‘Red List’ ● Other organisations & conventions (from the ‘***WFF***’ to ‘***CITES***’) ● Exploring the ‘*Earth Summit’* & *‘Rio +20*’ ● Examining the ‘poster species’ for conservation (giant pandas, mountain gorillas & Siberian tigers) ● The plight of vultures & penguins ● Zooplankton & oyster reefs (the inevitable collapse of marine habitats) ● ‘*Keystone species’* (from Asian elephants to sea otters) ● The sad plight of turtles

The global decline of fisheries: pollution, ocean warming & overfishing on an industrial scale ● The ‘Grand Banks of Newfoundland’ & the collapse of North Sea cod stocks ● The destruction of wild tuna: a fated genus of fish ● Exploiting stocks of deepwater fish & the ecological impact of indiscriminate bottom trawling ● The irreversible damage to the gene pools of countless marine species ● The global problem of pirate fleets & the additional consequences of illegal fishing ● The illusion of ‘sustainable fish farming’ & the profound dangers of ocean warming ● Genetic pollution & the growing threat to wild fish populations (the release of salmon engineered to carry hGH)

Eluding to the ongoing ‘Holocene extinction event’ resulting from human colonisation & industrialisation ● Entering the final extinction pulse & the tragedy of ‘*dead clades walking*’ ● Genetic erosion & ecological uniformity ● The human mismanagement of nature (the impoverishment of Hawaii) ● The folly of reintroducing captive species that have become ‘mimetically disadvantaged’ ● From the plight of Sumatran orangutans to reanimating ibex & mammoths ● A word on human ignorance & the wholesale decline of our planet’s biospheric integrity



Part 3: Human Malevolence

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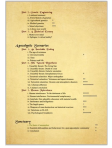
ii. ***Human interference****: environmental complacency*

The inconvenience of a'*global anthropogenic ecological catastrophe'* ● Blinded by the market economy: The invaluable contribution of healthy ecosystems ● The birth of agriculture & our intellectual evolution ● Industrial revolution & the growing burden of humanity (our burgeoning population & consumer demand outstripping our planet's regenerative capacity) ● The degradation of arable land & the growing strain on global food supplies ● The consequences of agricultural inefficiency: the decline of groundwater & other natural resources (biofuels & fertilisers) ● Modern civilisation & its dangerous addiction to fossil fuels

The critical importance of established water delivery systems & the regulatory role of forests ● The scale of destruction of the Amazon Rainforest & the Mata Atlântica ● The continuing exploitation of forest land in Brazil & elsewhere ● Clearcutting the Boreal: replacing natural forest with monocrop plantations ● Agricultural expansion & the accumulation of atmospheric CO_2 (Amazonia as a net carbon producer) ● Sulphur dioxide & the dangers of 'acid rain' ● An unwelcoming glimpse into the future of the Amazon

Expounding types of human pollution: its effect on biodiversity & human life ● Pollutants & their sources: the scourge of heavy industry ● Our ability to pollute in a myriad of ways (from intensive farming to radioactive contamination)

The scale of pollution: instant disasters - industrial accidents & malevolent intent (from the '*Amoco Cadiz'* to the *'Al-Mishraq fire'*) ● Long term environmental disasters: decades of DDT & other toxic



Part 3: Human Malevolence
(...continued)

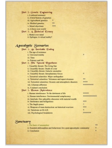
*ii. **Human interference**: environmental complacency*
(...continued)

pollutants ● Mercury pollution & the harrowing story of Minamata ● The environmental contamination of other dioxins (from H_2S to PCBs) ● The inescapable consequences of chemical pollution & its exacerbation through climate change (from industrial poisons to 'triclosan' ● Intensive farming & the rise of dead zones (from the Adriatic Sea to the Gulf of Mexico) ● The deteriorating health of oceans & waterways

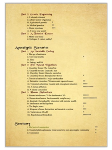
Plastic pollution, the '*North Pacific Gyre'* & the *'Great Pacific Garbage Patch'* ● The sad plight of Midway Atoll & the pollution of other oceanic gyres ● The anthropogenic production of ozone & its harmful effects ● 'Volatile organic compounds': the production of photochemical smog & the depletion of atmospheric ozone ● CFCs, HCFCs & the seasonal appearance of the 'ozone hole' ● The careless 'balancing act' between ozone-depleting pollutants & potent greenhouse gasses

The exploitation of atomic energy: radioactive decay - the most persistent & hazardous pollution of all ● Historic disasters: From '*Three Mile Island'* to *'Fukushima*' ● Cold War ignorance: the deadly contamination of Lake Karachay & the toxic landfills of Dzerzhinsk ● The murderous deployment of 'Agent Orange' in Vietnam & its continuing legacy ● Modern centres of industrial pollution (from Norilsk to Guiyu ● The deadly environmental consequences of China's industrial boom & its prioritisation of economic growth over food security & public health

A brief look at conservation charities & the unachievable prospect of complete environmental protection ● Atmospheric CO_2: examining the



Part 3: Human Malevolence *(...continued)*	*ii.* ***Human interference****: environmental complacency* *(...continued)*	consequences our huge carbon footprint & projected temperature rises ● Anthropogenic warming: its causes & effects (from rainforests to glaciers) ● Arctic warming (from the *'Northwest Passage'* to the *'Greenland ice sheet'*) ● The state of the 'Great Antarctic ice sheets' the effects of their demise & the inconceivable consequences of total ice loss ● A consequential decline of the Southern Ocean An introduction to '*positive feedback loops'* (Arctic ice & West Coast fog) ● Approaching '*tipping points*':The deteriorating *carbon sink effect* of the world's forests & grasslands (the inherent loss of 'old growth' trees & the inhibition of photosynthesis) ● The profound effect of warming temperatures on plant life : deadly environmental disruptions (from *BVOC*s to migratory shifts) ● The deterioration of habitats (from polar bears to golden toads) & the potential collapse of the food web ● From agricultural decline to shifting weather patterns ● The loss of phytoplankton & the apocalyptic demise of ocean life The rising economic cost of global warming & the stark consequences of shifting weather patterns (a look at the Amazon droughts) ● Explaining the '*Atlantic Multidecedal Oscillation*' (AMO) & its role in climate change ● Global warming & the frequency of catastrophic fires in North America ● Thermohaline circulation & the critical importance of the '*Atlantic Meridional Overturning Circulation* (AMOC) to life on Earth (a look at the dire consequences of a Gulf	



Part 3: Human Malevolence

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ii. Human interference*: environmental complacency*

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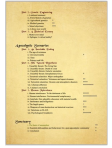
Stream / North Atlantic Drift shutdown

The definition of 'greenhouse gas' & a look at the most significant ones ● Water vapour ● Carbon dioxide (from the Miocene to Mauna Loa) ● Methane: the dangers of methanogenesis & the '*clathrate gun hypothesis*' ● Nitrous oxide & stratospheric ozone ● The extreme effects of synthesised gasses ● Black carbon & the effects of global dimming (from industrial pollution to contrails) ● Ionospheric shifts & the shrinking upper-atmosphere (the propagation of noctilucent clouds) ● Investigating the *'Gaia hypothesis'* (envisaging our planet as a self-regulating, holistic entity & understanding the scale of damage that human activity has caused)

James Lovelock

The irrefutable effects of climate change on human health ● Conflicts of interest: economic greed & our dependence on fossil fuels (the convenience of anthropogenic climate change denial) ● The unrelenting rise in CO_2 emissions & the unwillingness of world leaders to commit to non-binding agreements (from the ***'Rio Earth Summit'*** to the ***'United Nations Climate Change Conference'***) ● The inadequacies of the '***Kyoto Protocol***' & the wholesale abuse of '*carbon credits*' ● Some of the drastic measures required to mitigate the worst effects of climate change ● From the '***WMO***' to '***CAT***': the important work of climate agencies & research institutes ● The ***IPCC***: an international standard for climate science (controversies, reports & predictions) ● Understanding the temporary slowdown of warming at the turn of the century ● The dangers of climate intervention / climate engineering technology: carbon dioxide removal & solar radiation management (from *artificial trees* to the atmospheric injection of sulphate aerosols ● A lesson from '*Biosphere 2*'



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<td rowspan="3">Part 3: Human Malevolence
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<td>*Footnote:*</td>
<td>An attempt to formally explain the brief lull in the ongoing warming trend at the turn of the century</td>
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<td>*ii.* ***Human interference****:* *environmental complacency*
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Imagining a nightmare scenario where modern civilisation can no longer survive the effects of environmental decline ● The realities of dwindling freshwater supplies & fertile soils: a path to famine, disease & war ● Environmental mismanagement & the scramble for ‘precious’ resources (biocapacity, international friction & social fragility)
❁
Modern civilisation: its devastating effect on nature & a look into our annual consumption of fossil fuels ● Defining the ‘*Anthropocene*’ & the environmental cost of human existence ● Growing *carbon footprints* & diminishing resources: the practical & political challenges of dealing with climate change ● The perceived monetary value of invaluable natural assets: the ‘*Stern Review on the Economics of Climate Change*’ ● The relationship between environmental health & corporate greed: the shameful acts of powerful institutions ● The financial cost of exploiting nature (from deforestation to dwindling fish stocks)</td>
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<td>*iii.* ***Interlude****:* *our unhealthy obsession with material wealth*</td>
<td>Western values & the preoccupation with accumulating material wealth ● ‘*Wall Street*’ & the influence of American capitalism (from the ‘*California Gold Rush*’ to the ‘*Great Recession*’ ● The ‘*greater fool theory*’ (‘Black Monday’ and the ‘2008 global financial crisis’) ● Aggressive 1980s capitalism as the root of subsequent financial crises & the growing power of the wealthy elite ● Financial prejudice & the *housing bubble*: on the eve of economic crisis ● Austerity & national debt: the illusory world of financial markets trading dwindling resources ● The corporate mindset vs. environmental reality ● National defence vs. climate catastrophe</td>
<td>**Ronald Reagan | Margaret Thatcher**</td>
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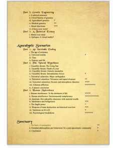
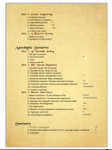
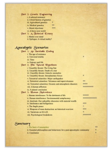


Part 3: Human Malevolence *(...continued)*	*iv. Intolerance and belligerence*	Behavioural modernity & the advent of war ● The 20th century: nationalism, industrialised conflict & formation of the '***United Nations*** ● Globalisation & Cold War rivalries ● The economic liberalisation of Chinese communism & Soviet stagnation ● The effects of the Soviet collapse in Eastern Europe (the Yugoslav wars & the rise of the Russian oligarch)	**Adolf Hitler | Deng Xiaoping | Vladimir Putin**
		Human conflicts at the dawn of the millennium: Kurdistan | Sri Lanka | Kashmir | African civil wars ● Russia & the West: the different attitudes towards engaging in foreign conflicts (from Afghanistan to Ukraine) ● The *Arab Spring*: from the spirit of hope to brutal suppression (& the genocidal control of land) ● Russian involvement in the Syrian civil war & Western lethargy (a history of costly interventions) ● The unforgiving nature of war & the horrific repression of Yazidi Kurds ● Western morality & the antithetical influence of Russia & China	**Abdullah Öcalan | Slobodan Milosevic | Bashar al-Assad | Xi Jinping | Vladimir Putin**
		Modern liberal democracy: capitalist excesses & political apathy (the weakening fabric of an established world order) ● Short-termism & the normalisation of extreme ideology: the fundamental flaws of Western democracy ● The rise of Christian fundamentalism in America & the concept of political morality (from Nixon to Trump) ● Populism & the portent of '*Brexit*' ● Assimilating the menacing ideologies of Putin & Xi with the American far-right	**Clint Eastwood | Arnold Schwarzenegger | Ronald Reagan | Jesse Ventura | Richard Nixon | Bill Clinton | George W. Bush | George H.W. Bush | Barack Obama | Donald Trump | David Cameron | Vladimir Putin | Xi Jinping**
		The slow decay of liberal democracies & their enshrined values (dwindling resources, overpopulation & foreign aggression) ● The rise of the American far-right: from ***'The Turner Diaries'*** to ***'Christian Identity***' (smothering rural communities with the politics of	**William Luther Pierce | Martin Luther King Jr. | George Rockwell | Adolf Hitler | Donald Trump | Eric Rudolph | Richard Kelly Hoskins | Terry Jones**

Part 3: Human Malevolence *(...continued)*	*iv. Intolerance and belligerence* *(...continued)*	'resentment & hate') ● Political terrorists & far-right vigilantes (the ***'Army of God'*** & the ***'Phineas Priesthood'***) ● 'Home-grown' terrorists, the rise of Islamophobia & the 'post-Trump' emboldenment of white supremacists (in preparation for a holy/race war)	
	v. The fragile peace	The psychology of war ✽ The industrial standardisation of warfare & the collapse of chivalry (from the Napoleonic Wars to the '*Lieber Code*') ● 'From the '*Haig Conventions*' to the '*Fourth Geneva Protocol'* (the inadequacies of arbitrary international agreements) ● Cold War mistrust & breaking the *'Biological and Toxic Weapons Convention'* ● The creation of synthetic viruses & the potential horrors of genetic warfare (the dangerous advance of unconventional military technology)	**Tenzin Gyatso** ✽ **Abraham Lincoln | Adolf Hitler | Joseph Stalin | Boris Yeltsin | Vladimir Putin**
	vi. Weapons of mass destruction: an historical overview	The truth about war & the use of weapons of mass destruction ● The invention, development & proliferation of nuclear weapons in the 20th century (from the '*Manhattan Project'* to *'START'*) ● Dangerous Cold War errors & nuclear brinkmanship ● The post-war nuclear world (from North Korea to Iran) ● A comparison between small tactical nuclear weapons & the largest conventional weapons (neutron bomb vs. '*FOAB*') ● Radiological dispersal devices (*RDD*s) ✽ A short history of chemical weapons: their early development during World War I (from mild incapacitates to the deadly horrors at Ypres) ● the further development of the choking agents *chlorine* and *phosgene* & the weaponisation of *mustard gas & lewisite* ● Germany's violation of the 'Geneva Protocol' & other inter-war agreements: the development of *tabun, sarin & soman* ● World War II & the horrors of *Zyklon B* ● The development & indiscriminate use of *napalm* by the US in Vietnam ● From *VX gas* to *novichok*: the most potent synthetic nerve agents ● The development of dangerous incapacitates (from *BZ*	**Neville Chamberlain | Albert Einstein | J. Robert Oppenheimer | Leslie Groves | Klaus Fuchs | Edward Teller | Stanislaw Ulam | Joseph Stalin | Samuel T. Cohen** ✽ **Fritz Haber | John Davy | Victor Grignard | Gerhard Schrader | Bruno Tesch | Louis Fieser | Ranajit Ghosh | Saddam Hussein | Bashar al-Assad**



Part 3: Human Malevolence

(...continued)

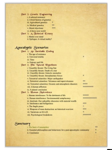
vi. Weapons of mass destruction: an historical overview

(...continued)

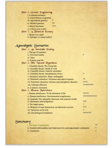
gas to *kolokol-1*) ● Herbicidal warfare: the introduction of *agent orange* & other powerful carcinogenic defoliants in the Vietnam War (the lasting effects of *TCDD*) ● The indiscriminate use of chemical weapons in later conflicts (from Halabja to Homs)

The weaponisation of life & the pros and cons of using biological weapons ● Historic instances of weaponising disease (from plague to smallpox) ● Industrial warfare & the birth of bioweapons programs (from anthrax to botulism) ● An insight into Japan's biological weapons research & development programs in the 1930s & 40s & the hideous experiments of '***Unit 731***' ● The complicity of post-war America in further bioweapons research ● The UK's short-lived research in to weaponised anthrax & the escalation of bioweapons development by the rival superpowers ● A look into the US bioweapons program during the Cold War era: from *Pine Bluff Arsenal* to *'**Project 112**'*) ● '***Biopreparat***' & Soviet defiance of the 'Biological Weapons Convention' (from *Yellow Rain* to *HIV*) ● Deadly accidents & intentional use: the creation of hybrid toxins & modified pathogens ● The stockpiling of biological weapons in the modern world

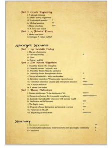
Shiro Ishii | Richard Nixon



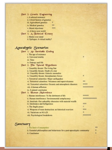
Part 3: Human Malevolence *(...continued)*	*vi. Weapons of mass destruction: an historical overview* *(...continued)*	Military might & the perceived advantages of investing heavily in military technology ● The practical limitations of nuclear weapons ● The ‘electromagnetic pulse’ & the development of ‘*super EMP weapons*’ - the consummate ‘doomsday device’ ● The likelihood of a co-ordinated EMP attack ● The deterrence aspect of WMDs & their perceived illegitimacy: the evolution of whole new kinds of weapon ● Genetic warfare: militarising ‘*CRISPR-Cas9’* & the endless range of bioengineered maladies that an enemy population could be made to suffer ● Cybersecurity & the dangers of ‘*amateur biohackers’, ‘ethnic weapons’* & *‘digital biology*’ ● The growing influence of AI systems within military hardware: lethal autonomous weapons (from ‘*microdrones’* to *‘killer robots*’) ● Technical advance: providing the military with new tools of death	

Part 3: Human Malevolence *(...continued)*	*vii. Variations on M.A.D.*	The inherent dangers of detonating a single nuclear warhead in anger ● A brief history of nuclear-armed nations & the '*Nuclear Weapons Non-Proliferation Treaty*' (NPT) ● Examples of Cold War nuclear crises & the proliferation of nuclear technology following the break up of the Soviet Union ● The role of Pakistan in nuclear insecurity & US paranoia in the Middle East ● Potential nuclear 'flashpoints' in the 21st century (from Kashmir to North Korea) & growing mistrust between former Cold War rivals ● The possibilities of nuclear conflict in the Russo-Ukrainian War ● Other potential nuclear disasters (from military accidents to rising discord)	**Abdul Qadeer Khan | Saddam Hussein | Vladimir Putin**
		The decay of 'social liberalism' & the consolidation of 'autocracy' ● The ethos of Western civilisation in contrast with oppressive regimes & the risk of escalating conflicts ● Speculative scenarios with WMDs: the Syrian civil war & the dangers of direct conflict between ***NATO*** & Russia ● Examining Putin's ambitions for Russia & himself ● Russia's relationship with Turkey & the possibilities of a Eurocentric war with NATO ● The Kashmir dispute between India & Pakistan ● Iran, Israel & the foreign interests of China ● The likely causes & outcomes of future nuclear conflicts ● Other 'doomsday scenarios' (from economic collapse to nuclear obliteration)	**Vladimir Putin**
	viii. Psychological breakdown	Humanity & the biggest threat to our continued existence: total war & nuclear deterrence ● The Western mindset & the fragility of modern civilisation in a world where the taboo of using WMDs is gradually being eroded ● 24 hour news feeds & the normalisation of human conflict: contrasted with the secrecy of Cold War flashpoints (from the mid-air break up of a B52 to the '*Able Archer/RYaN* crisis')	
		A look into outlandish 'endtime theories': no longer the reserve of religious eschatology (from *grey goo* to a *quantum vacuum collapse*) ●	**John F. Kennedy | Diana, Princess of Wales | King Hussein of Jordan | Yasser Arafat | Boris Yeltsin |**



Part 3: Human Malevolence *(...continued)*	*viii. Psychological breakdown* *(...continued)*	Everyday concerns & the influence of media news: events that profoundly effect the national psyche (from the death of JFK to 9/11) ● Media power at the end of the 20th century: 1999 - a year in news (from the death of King Hussain to the break up of 'MIR') ● Post-Cold War relations & the consequences of political upheaval in Russia (from Yeltsin's economic mismanagement to Putin's military miscalculation) ● '***Al-Qaeda***' & Western paranoia ● The growth of religious & political extremism in a world of unprecedented technological advance ● 'Whole genome sequencing' & the growing threat of bioweapons ● The choice of omnicide	**Vladimir Putin | Osama Bin Laden | Saddam Hussein**
		Nationality & the concept of 'belonging': fulfilling the human psyche ● The polarisation of religion & its threat to secular rationale ● Common sense atheism in the face of religious extremism (from far-right evangelists to ultra-Orthodox Jews) ● The Semitic '*Day of Judgement*': a chance for redemption & an excuse for genocide ● Non-Semitic doomsday cults (from '***Aum Shinriko'*** to the ***'Gaia Liberation Front***')	**Shoko Asahara**
		Cyberspace technology & the ongoing international arms race ● The subversive threat of military-grade malware & sophisticated cyber weapons (from '*Titan Rain'* to *'NotPetya*') ● The growing dangers of a *full spectrum cyberattack*	
		War, diplomacy & the purpose of national identity ● A look into the global arms budget & the expansion of ***NATO*** ● The concept of *full spectrum dominance* & the advanced cyberwarfare programs of the US, Russia & China ● The development of *directed energy weapons* (from 'railguns 'to 'masers') & the significance of military AI technology ● The destabilising effect of developing terrible new	**Ronald Reagan**

Part 3: Human Malevolence *(...continued)*	*viii. Psychological breakdown* *(...continued)*	weapons & growing international mistrust ● 'Awe-inspiring' weapons of war: exposing the psychology of *national pride*	
		Europe as the battleground for some of the bloodiest conflicts in human history ● The psychology of war (comparing the battles of Agincourt & Berlin) ● Modern European wars: Russian irredentism & the psychological dangers of protracted conflict ● War as a hotbed of radicalisation & moral decay ● From Nazi Germany to Bosnian Serbs: the warped realities of genocide & ethnic cleansing ● An attempt to portray some of the unimaginable horrors of war as a way to convey how atrocities are committed so readily at times of emotional imbalance ● The loss of wartime memories: the importance of archive film & collective remembrance ('*They Shall Not Grow Old*')	**Vladimir Putin | Peter Jackson**
		Recognising the duality of emotion: i.e. 'constructive '(+) & 'destructive' (-) aspects of human thought ● The exploitation of cultural values to justify war: the power of 'state propaganda' ● Keeping up with technology: a fatalistic view of humanity's destructive compulsions ● 'Common reasoning' & the collective realisation that '*the end is nigh*'	
		Human civilisation post-1945: the perceived effectiveness of nuclear deterrence ● Eroding 'denial' & the growing emotional intensity of an approaching nuclear conflict ● The increasing availability of WMDs & their inevitable use in the future: playing out the prelude to an 'end-time conflict' ● The ultimate cost of wilful human destruction & a thought on our final legacy	

Part 3: Human Malevolence *(...continued)*	*An ethereal footnote of subconscious thoughts*	The physiological transition between life & death: the subatomic impact of nuclear vaporisation ❁ Knowledge, imagination & the human mind: a perceptual journey beyond black holes ❁ Civilisation as an ethereal consequence of entropy: the growing pressures on society & our ultimate expression of chaos - nuclear war	

Part 1

An Inevitable Ending

"There is no god other than life itself"
~ **Acharya Rajneesh** 'Osho's Ten Commandments' *(1966)*

i.
(The age of existence)

We are all *totally* reliant on the Earth and the life-sustaining properties of its atmosphere. But Earthly life has not always existed and, by relying on a planet whose own life span is finite, inevitably the last living organisms on Earth will one day perish and die. The creation and destruction of life has, for millennia, been embedded in the domain of myth and religion, but it is through the pursuit of science that we have gained a far greater understanding of the precariousness of our own fragile existence.

As far as our Earth's age is concerned, up until the 18th century, Western opinion was firmly based on a literal belief in the ***'Book of Genesis'***. By applying a little religious cosmology to biblical texts, Christian scholars had worked out a numerological descent of *'Adam'* and *'Eve'*s lineage, and general consensus was that *'God'* created the Earth in approximately 4000**BCE**. By the mid-18th century however an emerging ***'Age of Reason'***, which had begun the previous century, gave way to an 'intellectual revolution of mind' known as the ***'Enlightenment' Period'***. It was a time when secular philosophy began to seriously challenge Christian theology, and our understanding of the Earth was naturally re-evaluated.

Important contributors to this new way of thinking included scientists and naturalists such as Russian polymath **'Mikhail Lomonosov'**, French naturalist **'Georges-Louis Leclerc'** ***(Comte de Buffon)***, and English geologist **'William Smith'** who extended estimates for the planet's age from 75,000 years upwards ~ far beyond the Christian comprehension of time. Of particular value was the work of pioneering Scottish geologist **'James Hutton'**. Hutton effectively discovered the concept of 'geological time', having reasoned that the Earth's surface was undergoing a perpetual physical transformation. He recognised that land was being eroded by weather and sea whilst being created by volcanic deposits in a continuous cycle, and so formulated a new scientific philosophy ~ ***'uniformitarianism'***.

Of course it was, by now, generally understood that different layers of rock couldn't possibly have formed at the same time *(whether created instantaneously by the 'hand of god' or precipitated from a single flood)*. Popular belief was now confronted with scientific rationale which opened up the concept of our planet being far older than previously imagined. Indeed Hutton himself proposed that there was a virtually infinite abyss of time between the present day and the original creation of Earth.

By the 19th century this atmosphere of secular reasoning had encouraged many notable geologists, biologists, mathematicians, astronomers physicists, and chemists to attempt to work out the Earth's true age. This quest was tackled by numerous scientists including **'Charles Lyell'**, **'William Thomson'** *(Lord Kelvin)*, **'Thomas H. Huxley'**, **'Hermann von Helmholtz'**, **'George Darwin'** and many others. Everything from planetary heat loss to tidal friction was taken into account, and independent proposals for the expanse of Earthly time ranged from anywhere between 20 million and 400 million years. With the discovery of radioactivity in 1896 however, came a whole new field of science and it was soon realised that radioactive decay was all around us ~ a process which offsets any cooling process that our planet may have otherwise undergone. By the start of the 20th century, a new method of measuring geological time had begun to emerge thanks to pioneering work from scientists such as New Zealand-born British physicist **'Ernest Rutherford'**, **US** chemist **'Bertram B. Boltwood'**, and English geologist **'Arthur Holmes'**. Initial studies into the gradual decay of uranium to lead, led scientists to eventually determine the half-lives *(or rate of decay)* of various radioactive elements. As technology improved, so the development of ever more reliable radiometric dating techniques emerged, and it was realised that the Earth has been in existence for well over a billion *(or 1000 million)* years.

Today it is recognised that the oldest known 'tangible' objects in our solar system, meteorites, are composed of the same primordial material as Earth. As our planet is undergoing perpetual change from core to crust, any reservoir samples of original terrestrial rock will have long been subsumed beneath its surface. Therefore meteorites provide us with the most accurate means through which to date our own planet's existence.

The Earth is now known to be about 4.567 billion years old ~ a figure first established in 1956 by **US** geologist **'Clair Cameron Patterson'**. It is currently believed that the surface of the Earth cooled enough to form a crust some 4.4 billion years ago. Condensing water from volcanic eruptions created the oceans which first covered the planet over 4 billion years ago. Over time the erosion of rock led to the creation of shallow 'mud' pools that were rich in chemical nutrients. These became home to the first micro-organisms, cyanobacteria, which emerged around 3.8 billion years ago. Their existence and ability to perform *'oxygenic photosynthesis'* profoundly altered the composition of the Earth's atmosphere, allowing more complex species of life to evolve and eventually flourish.

Many factors *(both terrestrial and celestial)* have shaped the development of life on our planet. With an oxygen-rich atmosphere and an abundance of liquid water on its surface, the Earth evolved a diverse biosphere. In addition our planet's comparatively large Moon *(which orbits our planet at 238,854 miles)* has brought tidal dynamism and steadied the Earth's axial oscillation, thus creating seasonal fluctuations. Yet the precursor for life is the existence of a single star whose ever-present source of energy is crucial to our own continued existence. Not only is the Sun responsible for breathing life into our planet, but without it our Earth could not even exist.

Situated approximately 28,000 light years from the heart of the Milky Way, the Sun is a middle-aged, 'third generation' star which was born from the remnants of a massive supernova event some 4.6 billion years ago. It completes one orbit around the galactic centre about every 250 million years, and it accounts for 99.98% of the entire mass of our solar system ~ excess matter caught within its monumental gravitational influence. Now believed to comprise eight planets, up to 200 dwarf planets, and well over 750,000 minor planets *(not to mention the thousands of comets and many hundreds of moons)*, the solar system took its present form within a few hundred million years of our Sun's creation. Yet, of all of these celestial bodies, only the Earth *(in a solar orbit of approximately 93.2 million miles)* has developed an atmosphere capable of supporting life.

Whilst we owe our continued existence to a four-and-a-half billion year old star we live in a physical Universe which is far older. Indeed our life-giving Sun is just one of around 400 billion stars in a single galaxy, and the observable Universe contains upto two trillion galaxies, many of which are considerably larger than our own Milky Way. Based on presently-accepted cosmological parameters, modern science holds the Universe to be between 12 billion and 15 billion years old. Indeed a number of projects have attempted to age the Universe using various models, with the most recent studies focusing on stellar nucleosynthesis, the carbon-nitrogen-oxyen cycle, and globular clusters, The most commonly held theory however is based on background radiation data provided by **NASA**'s ***'Wilkinson Microwave Anisotropy Probe'*** *(or* ***'WMAP'*** *~ launched in 2001)* which points to an age of approximately 13.8 billion years, with the first stars forming after about 380 million years.

In the context of a wider cosmos, the development of the first biological entities, and their subsequent evolution to today's advanced life on Earth is a freak of physical nature. However it has all happened through a logical, rather than miraculous, series of events. Yet, despite the undeniable rationale of *'natural philosophy'* and the subsequent 'methodological certainty' of '*modern science'*, at the turn of the 21st century there remains a growing persistence in the Christian belief of *'creationism'*. It is particularly prevalent in the **USA**, and the fanciful philosophy of *'theistic realism'* enables advocates to justify their unwavering belief in the pseudo-science of *'evolution by intelligent design'*. In the face of modern rationale, many religious institutions attempt to blur the distinction between science and faith, allowing such ridiculous hypotheses to gain wider acceptance. But humanity cannot afford to deny the plain reality of methodical science for only it can truly advance human knowledge and progress.

Thankfully serious science is far more pragmatic and logical than any supernatural belief however sacred it may be considered. Whilst those of rigid Christian faith may not accept the absolute validity of any great scientific theory *(no matter how conclusive it may be)*, the ultimate goal of many theoretical physicists around the world is to formulate the hypothetical *'theory of everything'*. This elusive theory would ultimately connect the fundamental forces of nature into a single model and therefore fully explain the interactions between all known physical phenomena ~ directly challenging the idea of 'divine creation'. Should a completely valid theory of everything become reality and establish a universal model for existence from which all others are a consequence, the age and lifespan of our physical universe could be readily determined, Not only that, but it would unite the two 'currently' accepted theories of *'quantum mechanics'* and *'general relativity'*. However, in doing so, it could also violate several principles that are currently accepted to be fundamental to nature.

ii.

(Universal totality)

Our present understanding of the Universe that surrounds us is largely due to the invaluable work of many scientists throughout the 20th century. In the last century a huge number of astronomers, astrophysicists, and cosmologists studied the make-up of our physical dimension. Eminent scientists, including theoretical and mathematical physicists such as **'Albert Einstein'**, **'Neils Bohr'**, **'Steven Weinberg'**, **'Stephen Hawking'**, **'Roger Penrose'**, and many others, have broadened our scientific understanding in the quest for universal knowledge. Today we recognise that the human species exists on an insignificant planet in an unimaginably large cosmos.

In terms of its size, the Universe is vast, and we can only see a tiny proportion of it. To give an idea of its extent, in 2016 astronomers using the ***'Hubble Space Telescope'*** identified a galaxy *(subsequently designated* ***'GN-z11'****)* that was approximately 13.4 billion light years away. At such a distance, it is believed to have been present a mere 400 million years after the Big Bang ignited ~ comparatively close to what is termed the *'cosmic renaissance'* when the first protostars formed.

Yet our own galaxy is not at the centre of the cosmos but, like all others, is accelerating outward from it. Indeed because time is relative to the speed of light *(which itself hastens with the expansion of space)*, the true size of the Universe is much bigger than 13.8 billion light years wide. If it is still in existence today, the **GN-z11** system, for example, would now be some 32 billion light years from us. According to *'Hubble's law'*, all but the closest galaxies are accelerating away from us at a speed that is directly proportional to their distance, and when you take into account 'co-moving distances', the physical dimension of our Universe has a diameter that is somewhere in excess of 93 billion light years.

The empiricism of science tells us that, here on Earth, we are but passengers within a Big Bang explosion some 13.8 billion years after its genesis. Originally proposed by Belgian astronomer **'Georges Lemaître'** in 1927, the Big Bang theory is a generally accepted hypothesis that is strongly backed up by the proven existence of *'cosmic microwave background radiation'* ~ a thermal 'blackbody' spectrum of photons which was scattered at a time when the Universe must have been much hotter. First predicted by Ukrainian physicist **'George Gamow'** in 1948, **CMB** radiation was inadvertently discovered by German-born **US** physicist **'Arno Penzias'** and **US** astronomer **'Robert Wilson'** at the ***'Bell Telephone Laboratories'*** in New Jersey, in 1965. Its existence has subsequently been confirmed by various astrophysicists and cosmologists throughout the 20th century, including **'Robert Dicke'**, **'David Wilkinson'**, **'George Smoot'** and **'John Mather'**.

At a mere 2.725° above absolute zero, **CMB** radiation is residual energy from a universal explosion and appears to be distributed evenly throughout the observable

Universe, providing compelling evidence for the Big Bang theory. However when it comes to studying what came before the Universe and what lies beyond, conventional science breaks down. Indeed understanding the very early Universe poses many problems for modern cosmology, and what happened before the ***'Planck epoch'*** *(after just 10^{-43} seconds ~ when the four fundamental forces of nature were believed to be in equilibrium)* can be no more than complete speculation. Only after the process of ***'spontaneous symmetry breaking'*** *(when gravity began to separate from the other three forces)* does quantum physics become relevant.

To all intents and purposes nothing occurred before the Big Bang because there was no space and time, putting such an event beyond empirical correlation. Likewise our inability to confirm the ultimate fate of the Universe through defined methodology has resulted in the advocating of many models for its ending. Yet just as frameworks and hypotheses such as Einstein's original ***'cosmological constant'***, and **'Fred Hoyle**'s ***'steady state theory'*** *(or 'standard cosmological model')* are now largely discounted by modern science, so scenarios such as the ***'big crunch'***, ***'heat death'*** *(or 'big freeze')*, and ***'false vacuum'*** are increasingly seen as unlikely outcomes.

Quantum mechanics and physical cosmology still provide us with a rational picture of our Universe's evolution and can offer a far more reasoned approach to cosmic 'end-times' than any theological belief could possibly do. Indeed the continuation of research into the fate of the Universe by physicists and cosmologists, such as **Richard A. Muller', 'Saul Perlmutter'**, and **'Eric Chaisson'**, have proved invaluable to our further understanding of it. The most credible models for the birth and death of our physical Universe incorporate well founded deductions. These include ***'inflation theory'***, developed by **US** physicist **'Alan Guth'** in 1981, and the ***'big rip theory'***, proposed twenty years later by **US** theoretical cosmologist **'Robert Caldwell'**. Whilst the former is broadly in line with our perceived 'large-scale structure of the physical Universe', the latter currently provides the most accurate paradigm for its ultimate fate.

Guth's model of 'cosmic inflation' infers a period of exponential expansion, one of several phases that the early Universe is believed to have undergone within the first second of its existence. However, whilst it may support the modern ***'cosmological principle'*** *(that the Universe is flat, homogenous and isotropic)*, the inductive reasoning behind such axioms remains questionable. Coldwell's 'big rip', theory meanwhile, describes a Universe that is still accelerating in such a way, predicting that within another 20 billion years even the smallest particles of matter will be torn apart. To concur with conventional thinking such a scenario would require an additional hypothetical force, ***'phantom energy'***, which equates to the effect of gravity in the presence of *'dark energy'*. As a universal force, it is the antithesis of Einstein's 'cosmological constant'.

Depending on which paradigm you adhere to, an open Universe could end anytime between the immediate future *(should a vacuum metastability event occur)* and roughly 10^{40} years *(should heat death eventually cause the decay of all protons)*. If the latter occurs, although matter may cease to exist, a cold dark Universe in the form of dispersed photons and leptons could potentially continue in an extreme low energy state for another 10^{1000} years. Yet even such a long time-frame for the mortal existence of our own physical dimension is overshadowed by what is known as the ***'relative state formulation'*** *(or many worlds interpretation)*, wherein every possible outcome to every event exists within its own history. Originally suggested in 1957 by **US** physicist **'Hugh Everett'**, such a model interprets a Universe with an infinite number of identical and non-identical dimensions, and it is not at odds with most current ***'superstring theories'***.

❁

The 'Big Bang' is the source of all kinetic energy in the Universe. Its singularity was *(and remains)* a 'point' in space-time where the temperature first exceeded 0 **K** *(-273.15 °**C**)* and it energised the ultimate chain reaction. From the dispersal of nature's four fundamental forces *(electromagnetism, the weak and strong nuclear forces, and gravity)*, our physical dimension was born. A massive explosion of sixteen subatomic particles allowed them to develop mass through the spontaneous creation of an all-pervading field ~ carried by a *(recently detected)* seventeenth elementary particle *(the **'Higgs-Boson'**)*. The scattering and attraction of free electrons and protons resulted in the formation of atomic nuclei, and the subsequent production of hydrogen and helium *(the most basic physical elements)* gave rise to cosmic microwave radiation.

Within its expanding aura was a young Universe comprising a very hot quark-gluon plasma. As it expanded, it became less dense and cooled enough for nucleosynthesis to take place, whereupon the initial transferral of primordial energy into matter *(and antimatter)* generated 'gravitational potential energy'. The uneven distribution of mass subsequently produced gravitational collapse, leading to the formation of ***'quasars'*** ~ the very first structures to exist. Hot spots of intense electromagnetic energy *(each emitting the equivalent energy of over a trillion [1000 billion] 'Suns')*, quasars caused the reionisation of hydrogen, giving rise to the earliest protostars and eventually the manifestation of new *(heavier)* elements.

As our Universe expanded in all directions within its self-created dimension of space-time, mutual attraction caused the resulting matter to be drawn together. This would eventually form many billions of galaxies, which themselves would collect into groups, clusters and superclusters within our dynamic universal dimension.

Just as absolute zero, or 0 Kelvin, marks the lower temperature boundary of our Universe *(and the upper limit of its 'parent dimension'),* so our physical world also has a finite upper temperature limit. Representing the most energetic state of existence possible within our cosmos, it is known as the ***'Planck temperature'*** and lies at 1.417 **x** 10^{32} **K** *(or approximately 141 million, 700,000 trillion trillion °**C**)*. Temperatures outside the extremes of absolute zero and the Planck temperature do not exist within the physical realm of our Universe and are therefore unquantifiable by means of conventional physics. However this mind-boggling upper temperature occurred in the earliest epoch of the Big Bang, and is reached at the event horizons of super-massive black holes which lie at the centre of all mature galaxies. These effectively act as ‘vacuums’ within space into which energy is drawn and broken down into its most fundamental state. Beyond this point further dimensions are created.

As far as our own four-dimensional Universe is concerned, everything that has ever existed began as energy created by minute quantum fluctuations at the heart of the Big Bang. Its origin is generally perceived as a singular point in space-time that was infinitesimal but very hot. At the furthermost distance from the Big Bang lies an extremely cold outer-boundary *(the light speed circumference)* of unfathomable size that envelops all of space and time. For many billions of years every constituent particle of matter and every photon of electromagnetic energy within our cosmos has been inexorably thrust towards this point. Indeed the further from the epicentre of our expanding Universe, the more potential energy is dissipated, reverting back to its kinetic origins. However even on this incomprehensibly large scale, energy is not destroyed, it merely becomes sparse and inconsequential.

Mathematical formulae for describing the precise mechanics of our Universe currently evades theoretical physicists, and its paradoxical nature lies beyond present scientific understanding. However, by applying intuitive logic most people have the capability of loosely visualising the true nature of our cosmos. In layman's terms the physical Universe can effectively be explained as a ‘static conduit’ through which matter passes from the Big Bang explosion, *(from which all energy was created)* to the outer reaches of a ‘light speed circumference’ *(where energy dissipates into a state of maximum entropy)*. At neither poles can matter actually exist, but all matter within our cosmos is created between these two extremes and blown *(or drawn)* through from one end to the other. All things within in it must have a beginning and an end. Beyond the light speed circumference lies a state of ultimate nothingness ~ a perfect vacuum at absolute zero, without time and space. Another way of looking at this infinite region is as an all-encompassing black hole that connects our unfathomable parent dimension to our own infinitesimally smaller one.

Yet the world of visible matter constitutes but a fraction of our Universe. Comprising only 4% atomic material *(the building blocks of all physical structures)*, the Universe is far more intricate in its make-up than can be explained through scientific observation alone. It is presently believed that so called ***‘dark matter’*** and ***‘dark energy’*** account for a vast majority of the Universe’s known mass. Indeed 22% of it consists of mysterious dark matter which, at temperatures below 2.725**K**, does not emit or reflect electromagnetic radiation through space, and can only be detected by its gravitational influence. Meanwhile an enormous 74% of the Universe’s mass is bound within a hypothetical constant known as ‘dark energy’ ~ believed by modern science to be responsible for the accelerating outward expansion of the known Universe.

Dark matter *(a universal phenomenon responsible for weakening the fundamental force of gravity)* is, in effect, a ‘reaction’ to the creation of physical matter. With all galaxies in the Universe being drawn inexorably towards a state of non-existence at ever-greater velocity, ‘intergalactic space’ is being stretched, and dark matter is the residue of star formation. Consisting of new *‘non-baryonic’*, elementary particles, it is effectively an imprint on the once empty space that has ever been occupied by every atom that has ever existed.

We, like everything else in our physical dimension, are on an accelerating outward-bound journey, wherein the most distant objects will become ever harder to detect. As we move ever nearer to the light speed circumference the cosmic horizon draws inexorably closer and the observable Universe shrinks. Whilst technological advance may enable us to see more of the cosmos than we have ever done before, there are clearly less stars in the night sky visible to the naked eye than there were millions, thousands or even a few hundred years ago. Conversely the elusive, but plentiful, 'dark matter' will, in time, become easier to detect.

Dark energy is an even more profound component of the Universe and can logically be seen to exist in several different ways. However to explain dark energy requires analogy. Imagine the young Universe as an expanding 'ball of atomic energy' which is increasingly pervaded with deep fissures of open space as it reaches into the absolute void beyond. This growing sphere is kept in existence by a continuous outward flow of electromagnetic photons emanating from its core. As they are forced outwards, some particles eventually form atoms and physical matter is created. But as energy at the leading edge of this sphere accelerates towards a light speed circumference it is consumed into the state of emptiness that completely envelops it. However the 'surface area' of this regenerating entity is far from forming a perfect sphere, rather its is severely 'cracked' ~ riddled with vast expanses *(of dark energy)* which penetrate deep inside the universal globe drawing matter and energy outward at an ever-increasing rate. From another perspective, our entire physical Universe can be likened to a slowly shrinking star with millions of points which reach out into the nothingness beyond, each one consisting of a supercluster of outward bound galaxies.

There are of course alternative models of an open Universe which appear equally plausible. One such model predicts that all matter only forms within a narrow band around a globular nucleus, giving the impression of a flat Universe *(as demonstrated by **CMB** radiation observations)*. Whilst the Universe as a whole accelerates outwards in a spherical formation, either side of this plain of matter is nothing but *energised* empty space whose quintessence permeates the visible cosmos. Another model describes a Big Bang that is no longer feeding the physical Universe with energy. In this model the cosmos can be visualised as an expanding halo, thinning as it reaches outward towards a 'light speed boundary' into which it will eventually evaporate. In such a scenario the growing emptiness that pushes our cosmic halo into the surrounding void could also account for the missing mass of dark energy. However quantum theory does not allow the void within to reach a state of maximum entropy.

Then there is the model that envisions the Big Bang as an explosion whose energy was concentrated on the expanding perimeter of the Universe *(as opposed to being at the centre of all creation)*. In such a scenario, galaxies and stars would have formed in the 'wake' of the explosion which, effectively 'dragged' matter outwards as it moved ever further into the distance. Some 14 billion years after it passed the present position of the Earth, Big Bang energy would now lay far beyond the cosmic horizon and will have long since evaporated at the light speed circumference, leaving the visible but fading cosmos to follow it into oblivion. Whilst accounting for dark energy and its effect of outwardly accelerating matter, such a model contravenes many basic principles of modern cosmology. It is therefore more logical that the very explosion that created our dimension continues to feed a living Universe from within.

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iii.
(Time)

Whilst dark energy and dark matter may be mysterious constituents of our Universe, another equally curious element is *time*. Often referred to as the fourth dimension, time is better perceived as being the first, for without it there can be no space for anything physical to exist. Indeed the universal expansion of space can only persist thanks to the continuance of time.

The most accurate system we currently have of timekeeping is the *atomic clock* which registers the passing of time by measuring the resonance frequencies of caesium-133 atoms. Yet, whilst the most advanced clocks may be precise to within a 10 billionth of a second per day, atomic oscillations still require an albeit minuscule volume of space to occur, and space *(as we know from Einstein's* ***'General Theory of Relativity'****)* is warped by the existence of mass.

Time however can only truly be perceived as an *a priori* intuition because only its passing can be measured ~ time itself cannot. Furthermore, contrary to conventional science, time *(like mass and length)* cannot be a true fundamental quantity. Being restricted to a single time frame, we cannot directly detect any changes in the flow of time which, whilst appearing to be a fundamental constant *(like the speed of light in a vacuum)*, is actually accelerating. The idea that time speeds up as all matter in the Universe is thrust ever-faster outwards in three dimensions seems to contradict **'Albert Einstein'**s ***'Special Theory of Relativity'*** which holds that time runs slower the faster an object travels. However this only appears to be the case because we cannot record time simultaneously from more than one spatial reference frame.

Apparent confirmation of 'special relativity' has come from the famous experiment in which two synchronised atomic clocks are found to differ by a fraction of a second when one has been taken on a high speed journey around the world. Yet in order for comparative measurements to be made, both clocks <u>must</u> return to the same space-time, creating the illusion that time for the travelled clock has run slower. This is because it does not travel parallel to the so called ***'arrow of time'*** *(i.e. moving directly outward from the Big Bang)* ~ such a feat is physically impossible without countenancing the natural direction of universal expansion. Were this possible the atomic clocks would have to be over 21,500 miles apart, and the travelled clock would actually register more time *(effectively ageing faster than the 'stationary' clock)*.

One of the most interesting features of time is that, contrary to the theory of general relativity, it is not smooth and continuous but is actually 'quantised' ~ i.e. it ultimately comprises of individual units or 'packets'. In accordance with quantum theory, the most basic unit of time is defined as 5.4 x 10^{-44} seconds *(or approximately 54 million, trillion, trillion, trillionths of a second)*. Known as ***'Planck time'***, this imperceptible figure represents the smallest possible time span and therefore a fundamental lower limit to physical existence in our Universe. Indeed, because time and space are so profoundly interwoven, Planck time effectively delineates the lowest possible state of energy below which photons are not emitted.

Were we able to take a snapshot of the Universe in its very early stages, when nucleosynthesis began *(after a mere second of existence)*, it would appear as a ball of energy a little smaller than the size of our own Sun. It stands to reason that photons of light at its surface will have taken just a second to reach that point, whereas the radiation of a single photon to the frontier of today's much larger Universe would take billions of years. Yet this is not the case. To an observer travelling the radial journey from universal centre to outer boundary at light speed, the journey time would appear to be no different than it would have when the Universe was much younger and smaller. Indeed, because photons can only move at a speed relative to the space they occupy, the time taken for light to pass from epicentre to horizon is the *only* universal constant.

Without this state of *'photo-equilibrium'*, the Universe as an expanding physical entity simply could not exist. Yet in order for this fundamental law of nature to occur, the speed of light has had to increase with the physical expansion of the Universe. It is all made possible by the spontaneous creation of time; a primary element of the Big Bang explosion and the driving force that continues to stretch space. Because it is quantized, there are far more 'units' of time in today's cosmos than there were during the very early Universe, but each one accounts for a far smaller percentage of *universal time*. In other words a 'second of time' when the Universe first underwent nuclear fusion, is the equivalent of several trillion seconds in the Universe of today. Whilst the time taken for light to reach a universal outer boundary may not change, relative time actually speeds up for any particular object as it moves on its universal outward journey.

There are several ways to visualise this phenomenon. For example, if we could hypothetically travel back far enough in time and witness the birth of the Universe, the Big Bang would appear almost instantaneous. However were we able to bring the actual Big Bang explosion forward to watch it unfold within our own reference of time, the initial reactions of this event would take an aeon to occur. From another perspective, suppose at the turn of the 21st century someone had invented a telescope powerful enough to reach far beyond the most distant galaxies that we can currently observe ~ allowing us to see the Big Bang explosion still unfolding in its infancy. This would be possible because it would have taken around 14 billion years for the light to reach us, and we would effectively be looking back in time to see our Universe in the making. Yet regardless of whether this technology had become available a thousand years earlier or a thousand years later, we would still be able to witness exactly the same event unfolding. Indeed all earthly time must occur within the confines of original space-time.

Even more mind-boggling is the fact that the pace at which time is shrinking is also quickening. Whilst the initial reactions within first second of the Big Bang may have taken forever relative to our own time reference, the continuing expulsion of energy at source is actually accelerating. The speed of light *(and therefore time)* is therefore also accelerating from within. So not only is every object getting ever-faster as it reaches the light speed circumference, but matter at any particular *'cosmic co-ordinate'* is travelling faster than it once did. An easy way to perceive this is to imagine our galaxy passing through the same region of open space that was occupied by another one a million years earlier. The stars and planets within our Milky Way will actually be hurtling past the same *hypothetical reference point* much faster than other celestial bodies once did. In other words, the *'Hubble Perimeter'* is hastening as the light speed circumference is inexorably retreating inwards towards the epicentre of the Big Bang. This means that the diameter of our cosmos is actually shrinking and, in accordance with the *'big rip theory'*, will effectively 'burn itself' out.

In effect, time is accelerating whilst space is actually withdrawing. However, by assuming 'fundamental' axioms, contemporary science is largely guilty of confusing space and time. Indeed the conventional idea of a *'space-time continuum'* is somewhat misleading as our singular experiences ultimately belie the realities of physical existence within an expanding Universe. The most blatant and obvious illustration of this can be found in the relative position of galaxies in the night sky. These appear to have remained unchanged for millennia, yet we know that all distant galaxies are moving away from us *(and each other)* at proportionally faster velocities. However, from experience all they appear to do is gradually fade, over time, from view.

As for ourselves, we are most certainly not alone in the cosmos, yet we are far too isolated to have any realistic chance of making contact with extraterrestrial intelligence. Our planet Earth is the only one we know of that can sustain advanced life and is, in itself, insignificant when compared to the grand scale of the Universe. Alas any like-minded beings from other worlds are likely to be many light years away. Furthermore, just as carbon-based life can only exist in a narrow band of planets or moons around any particular star or 'gas giant', so matter itself has a limited region in the Universe within which it can exist. Our dynamic multidimensional cosmos doesn't have a defined end but, by existing within it, our evolutionary course *(like that of every life form, planet, star and galaxy)* most certainly does.

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iv.

(Entropy and life)

The existence of life, wherever it may occur within our cosmos, is statistically highly implausible. Yet the Universe is so vast that, within it, biological ‘oases’ are a virtual certainty. Earthly life, for example, exists on a ‘knife edge’ and the human race is the product of an amazing series of chance events; both celestial and terrestrial. Like every other species of life, our very existence depends on an unusual property that is unique to the biological world ~ namely our apparent resistance to entropy *(or the natural dissipation of energy within the Universe)*.

In 1954, Russian-born Belgian theoretical chemist **‘Ilya Prigogine’** clearly explained how successive generations of living organisms were able to resist this universal inclination towards disorder. Moreover he provided mathematical proof that organic structures were capable of self-organisation by utilising free energy ~ thus effectively countering the chaotic inclination of our Universe. Prigogine’s work had a profound effect on many scientific and social disciplines.

The reorganisation of dispersed energy by living systems appears to break the second law of thermodynamics, with biological growth effectively creating a contra-flow to the natural entropy of universal existence. Indeed, whilst all ‘inanimate’ forms within the Universe are gradually, but relentlessly, ‘eroded’ towards a state of energy equilibrium, life successfully counters this force. In 1982 **US** biochemist **‘Albert Lehninger’** showed that living systems are able to do this because, whilst they may create internal order by utilising sunlight and nutrients, they return used energy to their surroundings in the form of dissipated heat ~ ultimately contributing to universal entropy.

Although living organisms appear to achieve immortality through reproduction, the millions of different species of life on Earth do not in fact break this universal law of increasing entropy. Cosmological disorder ultimately has the upper-hand thanks to something that we are mostly incapable of perceiving; namely the hastening ‘march of time’. Life cannot overcome the fact that each moment passes faster than the last, and, whilst time to us remains a constant, our lives are actually shortening by the ‘second’. To look at it another way ~ although human life expectancy has largely increased throughout the years, our distant ancestors will have actually lived for longer because the passing of time itself was slower. Conversely the lives of our descendants are guaranteed to be shorter even though many may well live to be over 120 years-old. Longevity may increase, but every subsequent generation exists when our galaxy *(and therefore our own planet)* is accelerating away from the Big Bang epicentre at a higher velocity. This difference is perceptually immeasurable as we are physically bound by our own space-time, but it leaves us with little more than a subtle feeling that the years seem to pass quicker as we grow older.

Of course it can be argued from a psychological perspective that the apparent quickening of time occurs because, as we age, each year that passes constitutes a smaller percentage of our life experiences. Yet however old we may live to be, as mature adults, we become increasingly aware that our own lives are fleeting. Indeed the only certainty of life is death, and every living individual of every species must eventually succumb to the eternal process of disintegration.

Meantime our collective actions, as a thinking species, are not incompatible with the outward flow of energy experienced within our four dimensional physical Universe. With the Earth's natural resources at our disposal, every day we consume an ever-growing amount of energy. Of course energy cannot be destroyed, and as our planet is thrust inexorably outwards from the centre of the Universe at ever faster speeds, so we too dissipate potential energy at an ever greater rate. Despite the best efforts of well intended individuals and organisations, this trend appears unstoppable and irreversible. However it is clearly not sustainable indefinitely, and when the outlet for our energies is stifled by the inevitable exhaustion of our once bountiful Earth, global civilisation will invariably topple. Starvation, disease, anarchy and war will no doubt prevail, with the ultimate destructive legacy of humanity likely to be the first use of a hydrogen bomb in anger.

Although we will forever live on in other dimensions, our eventual annihilation in this one is assured, In this physical world nothing is permanent ~ not even human consciousness. That is our mortal dimension.

Part 2
The Natural Hypotheses

"This is the way the world ends, not with a bang but a whimper."
~ **T.S. Eliot** 'The Hollow Man' *(1925)*

i.
*(**Unearthly threats:** The living Sun)*

Of the many trillions of stars in the Universe, we, and all other known living species, are the creation of but a single one ~ our Sun. It is the giver of life as we know it, and has the capacity to take it away in an instant.

Compared to other stars, the Sun, however, is nothing special. It is a medium sized star and, like all other active *(or 'main sequence')* stars, is largely composed of hydrogen. At its core, temperatures reach some fourteen million**ºC** where this most basic of elements undergoes the continuous process of nuclear fusion, keeping the star's visible surface *(or 'photosphere')* at a steady 5,500**ºC**. Beneath the surface, hydrogen atoms that have been ripped apart release free protons and electrons which produce powerful magnetic fields. From time to time these fields inevitably snap, creating unimaginably huge explosions that burst through the photosphere and eject loops of plasma into the Sun's outer atmosphere *(or 'corona')* where temperatures can reach in excess of two million**ºC**. Most of this solar plasma is dragged back to the surface by its enormous gravity, however the largest explosions can overcome the star's gravitational pull. These *'coronal mass ejections' (or **CMEs**)*, each containing several billion tons of matter, rapidly expand as they are expelled deep into the solar system.

During intense sun storms, solar flares are relatively abundant. Emanating from sunspots, the largest flares will often precede a coronal mass ejection which can hurtle hot plasma into space with a force of over a trillion, trillion joules of energy. Even the most modest of **CME**s contain the equivalent power of some ten million hydrogen bombs, with the largest escaping the Sun's gravity at a velocity of around two million miles-per-hour. Fortunately a vast majority of **CME**s miss the Earth because it presents a very small target within the vast expanse of solar space. Depending on their polarity, those that do strike our planet however either buffet its magnetic field or disperse huge amounts of energy within it. Indeed they can be unimaginably powerful with the potential to literally blow our atmosphere away.

For many thousands of years, the Sun has had a unique status at the centre of human mythology, either as a miraculous godly creation or worshipped as a deity in itself. By the early 17th century however the first serious scientific studies had begun in earnest following the earliest observations of sunspots *(short-lived cooler regions on the surface)* by Italian astronomer **'Galileo'** in 1610. Yet it was not until the 19th and 20th centuries that the Sun really began to give up its secrets to science. Having started a meticulous study of sunspots in 1826, within seventeen years German astronomer **'Samuel Heinrich Schwabe'** became the first person to document a variance of solar activity that appeared to peak once a decade. The century also saw the birth of spectroscopy, with great advances being made by German physicists including **'Joseph von Fraunhofer'**, **Robert Bunsen'** and **'Gustav Kirchhoff'** ~ allowing hydrogen to be identified, in 1859, as the main composition of the Sun. In the same year British astronomer **'Richard Carrington'** became the first person to observe a solar flare, and by 1908 **US** astronomer and inventor of the *'spectroheliograph'*, **'George Ellery Hale'**, had established that sunspots contained strong magnetic fields. 1962 saw the launch of the first in a series of nine ***'Orbiting Solar Observatories'*** sent to study the Sun and, by 1971, **US** astronomer **'Richard Tousey'** became the first to detect a coronal mass ejection using data from the seventh of these satellites. Of the many prolonged studies into solar activity today, one of the most extensive continues in America at the ***'National Oceanographic and Atmospheric Administration'***s *(or 'NOAA's) 'Climatic Data Center'* based in Asheville, North Carolina.

It is now known that the frequency and intensity of sunspots, solar flares and **CME**s vary according to a solar cycle of approximately eleven years, with each peak of activity *(or 'solar maximum')* alternating in magnetic polarity. This happens because the Sun acts like a giant twisting magnet, with field lines being contorted as chromospheric plasma at the equator and poles spin at different speeds. Solar maximum occurs when the star's magnetic equilibrium is violently re-established ~ this is when the Sun can be at its most dangerous to life on Earth.

Coronal mass ejections generally take between two and three days to travel the 93 million miles to Earth but the most powerful can reach our planet in a matter of hours. At the leading edge of these high energy radiation storms are the solar flares which, travelling at light speed, take a mere eight minutes to reach Earth. Of the comparatively few sun storms that actually head directly towards us, the extent of destruction that they can reap will ultimately depend on their magnetic field orientation.

Those that match the Earth's magnetic polarity when they hit, are largely repelled by the magnetosphere ~ a protective shield that prevents solar radiation from harming the planet's fragile biosphere. Taking the brunt of any force, the magnetosphere can be severely warped and temporarily weakened by sun storms and the upper atmosphere can become highly electrically charged. At higher latitudes, where the Earth's magnetic field is at its weakest, the solar wind can be seen as aurora *(the Northern and Southern Lights)* as it energises gas particles within the atmosphere with excessive numbers of protons and electrons. A **CME** that strikes when the Earth presents 'unlike' magnetic field lines towards the Sun is naturally attracted, penetrating the ionosphere and permeating the lower atmosphere. Depending on its ferocity, the effects of this can last anything from a few days to several years.

CMEs can cause extreme conditions in Earth's meteorological climate. Intense solar activity is curiously proportionate to the amount of electrical charge that airborne water droplets here on Earth can hold. Sun storms carry electrical currents that ionise the upper atmosphere, which can in turn lead to the seeding of clouds in the lower stratosphere. This natural seeding of clouds will often induce rainstorms, reducing atmospheric water vapour, thus allowing the Sun to warm the Earth's surface more directly. Indeed there is a clear correlation with temperature records on Earth and solar cycles. Between the mid-17th and early 18th centuries for example, the Sun underwent a period of comparative inactivity *(the 'Maunder Minimum')* which coincided with the coldest years of what is now known as the *'Little Ice Age'*. However, although subtle changes in the Sun's behaviour may have dramatic effects on Earth, solar activity is not the principle cause of today's global warming. Whilst this connection is a convenient truth for those who deny the drastic human contribution, a belief that intense cosmic rays are solely responsible for global warming is ill-founded.

A more immediate consequence of coronal mass ejections has become increasingly apparent over the years as we have become reliant on ever more sophisticated technology. In today's hi-tech world, our continued existence has a far greater susceptibility to the Sun's temperament than it ever has in the short history of civilisation. Indeed **CME**s are known to be capable of wreaking enormous damage to the infrastructure of human society. The largest produce enough electrostatic discharge to cripple the very technology that we rely on in our everyday lives, and could initiate any number of global catastrophic events.

Violent geomagnetic sun storms ultimately have the capacity to isolate large parts of civilisation, knocking out satellites and disrupting global telecommunications. They have the potential to severely damage the transmission of mains electricity ~ destroying vital transformers and overloading power grids with excess electrical current. In doing so they can paralyse vital systems such as air-traffic control, hospital equipment, rail networks, traffic signalling and even national defence systems. In a worst-case scenario, a particularly potent **CME** could indirectly vitiate the production and distribution of food to millions of people in urban areas, and disable other basic necessities including water supplies and sewage treatment. Such an event would inevitably precipitate the breakdown of society with hunger, disease and social anarchy stretching emergency services to the limit. Indeed the largest affected cities could take several decades to recover from such a catastrophe.

Although this is an extreme example, we have already witnessed a taste of what damage coronal mass ejections can do to the human world. 1859 saw the largest sun storm in recorded history. It gave rise to aurora that could be seen over two-thirds of the planet's skies, and severely damaged telegraphic communications across the industrialised world. In 1989 a **CME** with a southward magnetic direction struck the northern hemisphere having an even more dramatic effect. With a magnetic flux density of around 200 nanotesla, it created aurora that were seen as far south as the Mediterranean zones, but its most pronounced effects were felt over North America. It brought about general atmospheric mayhem, paralysing electronic communications, disrupting air traffic, and causing satellites to malfunction. Built on non-conducting granite bedrock, Quebec in Canada was particularly effected. Here electric current could not discharge into the ground, and most districts experienced complete blackout within ninety seconds. Some seven million homes lost power and the regional distribution grid took weeks to repair, creating a regional economic disaster.

Whilst the destructive sun storms of 1989 coincided with an active peak in the solar cycle, the next peak in 1999-2000 failed to materialise in such a calamitous way. Of course, however, an apocalyptic reverence of these years generated much interest in solar activity amongst doomsayers and others *(including those in denial of the human influences of global warming).* Many foresaw an abrupt increase in sunspots over the new millennium, and believed that the Sun had entered a critical phase in a longer cycle. Indeed the idea of a longer term cycle lasting several thousand years even gained a degree of interest within the scientific establishment.

Of the science-based theories surrounding the existence of such cycles, the most sound is based on the idea that fluctuations in the Sun's core contributes to a build up of stress within the *'tachocline'* ~ a narrow boundary between the star's *'radiation'* and *'convection'* zones some 300,000 miles beneath its surface. Over time this strengthens the magnetic fields here which, over a period lasting some 41,000 years, burst through the photosphere as increasingly more intense sunspots. Another, less studious, concept envisages that the spin of liquid and gaseous mass at the Sun's equator will eventually become sufficiently disproportionate to that rotating at its polar regions as to cause the star's magnetic field to 'snap', and *(somewhat like a spring)* abruptly retract; throwing out more plasma than in any other time in human history. Despite such dramatic projections, the next solar maximum *(which peaked in 2014 ~ three years later than anticipated)* turned out to be one of the weakest on record. Whilst also proving to be comparatively mild, the current solar cycle *(the 25th to be scientifically observed)* is considerably more active than the last, and is expected to reach solar maximum in the mid-2020s.

As and when the next **CME** heads directly towards us, its polarity will be crucial to the amount of damage it will do to our vulnerable planet. It may pass relatively unnoticed or could bring about physical destruction and social chaos on an unprecedented scale. At its worst, a sudden increase in solar activity causes the Earth's upper atmosphere to swell, and could potentially throw out every one of the 900-or-so working satellites, as well as alter the stabilised orbits of thousands of pieces of manmade debris around our planet.

Of course the relative orbits of these objects are closely monitored by various national security outposts across the globe. Perhaps the most sophisticated of these is the ***'North American Aerospace Defense Command'*** *('NORAD')* facility, in Cheyenne mountain near Colorado Springs, which continuously tracks some 8000 objects *(largely satellites, old rocket parts and other space flotsam)* in orbit around the Earth. A shift in trajectory in any one of these has the potential to cause a collision, and should a satellite spin out of control and fall to Earth in a populated area, defence establishments such as this ensure that it would not be mistaken for an incoming missile. However by damaging sensitive satellites and blinding tracking systems, such a solar storm would bring about military paranoia, and increase the risk of global war. The fear that various terrorist organisations could exploit the situation is eclipsed only by the fact that the world's nuclear powers recognise a geomagnetic storm as being the prime-time for any pre-emptive strike ~ should they ever consider it to be an 'acceptable' option.

A less obvious consequence of sun storms is their direct effect on human health. Solar flares and **CME**s can surround us with an excessive amount of electrons and protons, and the electrical charge of particles in the atmosphere corresponds to the doses of radiation we receive in our everyday lives. Nearly all forms of life are susceptible to an increase in atmospheric radiation, and solar flares naturally bring about a rise in associated diseases. Besides causing various cancers and indirectly increasing the risk of other conditions *(such as heart attacks and allergies)*, sun storms can also have a pronounced psychological effect on the general populace. In charging the atmosphere, they can actually affect the chemical state of our brains, inducing subtle alterations to its electrical impulses. This actually increases the erraticism of emotion within exposed populations and even brings about a rise in the number of accidents caused by human error.

Such is the interest *(and concern)* surrounding the star on which we so heavily depend that, over the years, numerous satellites and probes have been launched specifically to study our precious but very dangerous Sun. Between 1962-75 *'**NASA**' (the 'National Aeronautics and Space Administration')* launched a series of nine 'Orbiting Space Observatories' designed to investigate solar radiation. The next stage of investigation was heralded by their ill-fated ***'Solar Maximum Mission'*** *('Solar Max' ~ launched in 1980)* which, after extensive instrument repair, ironically became a casualty of the destructive 1989 solar storm, burning up in the atmosphere later in the year. Differing degrees of success befell **NASA**'s ***'Ulysses'*** and ***'Genesis'*** probes *(launched in 1990 and 2001 respectively)*, though both revealed much about the make-up of the solar wind.

America however was not the only nation to invest in solar exploration in the late 20th century. In 1991 a collaboration between **NASA**, *'**ESA**' (the 'European Space Agency')* and the Japanese ***'Institute of Space and Astronautical Science'*** agency *('**ISAS**')* culminated with the launch of the ***'Yohkoh'*** *(or 'Sunbeam')* satellite from the Kagoshima Space Centre in southern Japan. During its operational lifetime Yohkoh revealed the Sun's corona in extraordinary depth. Perhaps the most celebrated solar mission of the 20th century though came as the result of the ***'International Solar Terrestrial Physics Programme'*** which also brought together the joint expertise of **NASA** and **ESA**. The resulting satellite, ***'SOHO'*** *(the 'Solar and Heliospheric Observatory')*, was launched from Cape Canaveral in Florida in 1995. **SOHO** was positioned some 930,000 miles from Earth, directly between ourselves and the Sun, in a region where the star's gravitational pull is offset by that of our own planet ~ thus allowing centripetal force to keep it in an identical orbit. By orbiting the Sun around a point of neutral influence, its instruments were able to examine the Sun's corona with extraordinary detail. Importantly it could measure the frequency and determine the direction of **CME**s ~ distinguishing between the majority that are released into the solar system beyond and those that are aimed directly at us. Though initially problematic, **SOHO** has also given us great insight into Sun's interior and has continued to gather valuable data far beyond its original life expectancy.

Whilst the **SOHO** satellite provided a means of continuously monitoring the Sun, **NASA**'s ***'Advanced Composition Explorer'*** *('**ACE**' ~ launched in 1997)* further enhanced our understanding of it. Placed in orbit around the same 'liberation point' as its predecessor, **ACE** was designed to detect and compare the composition of solar material, and its onboard magnetometer enabled the magnetic field direction of approaching plasma clouds to be measured. Although its reliability remains questionable, the **ACE** mission has proved invaluable to present solar forecasting. A year after the **ACE** mission began, **NASA** launched *'**TRACE'** (the 'Transition Region and Coronal Explorer')*. Sent to investigate the transferral of energy particles to the Sun's outer-atmosphere, **TRACE** also enabled astronomers to study the fine structure of coronal loops, returning high resolution images correlated from various wavelengths.

The most important solar missions to have commenced at the start of the new century include ***'Hinode'*** *(or 'Sunrise')* launched by the ***'Japanese Aerospace Exploration Agency'*** *('**JAXA**')* in 2006. Equipped with both an optical and X-ray telescope, as well as an *'Extreme Ultraviolet Imaging Spectrometer'*, the Hinode probe makes continuous solar observations. In the same year **NASA**' launched its ***'Solar Terrestrial Relations Observatory'*** *('**STEREO**')* which combined two identical orbiters, each with an array of heliospheric imagers. By placing each sister craft in heliocentric orbits either side of the Earth, **STEREO** provided three-dimensional observations of solar winds, coronal mass ejections and the Sun itself. With **NASA**'s '***Solar Dynamic Observatory'*** and '***Parker Solar Probe'*** *(launched in 2010 and 2018 respectively)* both observing the solar atmosphere in unprecedented detail, our understanding of the star that sustains life on our planet continues to grow. Indeed, all of these satellites and probes collectively provide enough data to make increasingly accurate predictions regarding solar activity and the triggering of **CME**s in our direction ~ lengthening advanced warnings of such events.

ii.

(Unearthly threats: *Death of a star)*

Nothing in our physical Universe is permanent and our Sun is no exception. Forming around 4.6 billion years ago from the shock waves of a powerful supernova, as an active star the Sun has a finite life span and is now considered to be roughly middle-aged. As it has matured, its output has steadily increased to the point where the star currently converts some four million tons of its physical mass into electromagnetic energy every second. Indeed photospheric temperatures are believed to be approximately 25% higher today than when life first emerged on Earth some 3.8 billion years ago. However, as a 'living' star, the Sun cannot sustain fusion reactions indefinitely. It will eventually run out of hydrogen fuel and start to die within another five billion years.

The eventual death of our Sun as a main sequence star is of little concern to us now, but should life still cling to Earth over the next few billion years it will have to contend with *(and eventually succumb to)* a number of dramatic changes in the star. When its hydrogen supply is exhausted, the Sun's core density will increase considerably as it contracts, with rising temperatures eventually forcing the fusion of helium. Whilst its core will shrink, excess helium will cause the star's surface to expand, possibly increasing to over a hundred times its present size.

As a cooler but much brighter *'red giant'*, the dying star will have a devastating impact on the solar system ~ consuming Mercury and Venus and making our own planet too unbearable for life to continue. Although it may not actually engulf the Earth, the Sun's huge size and loss of mass are more likely to cause our planet's orbit to drift outwards. With most of its atmosphere having escaped, and its oceans long since evaporated, the Earth will become a hot molten world devoid of life, but the Sun will not have finished yet. After a further billion years or so, the Sun will be unable to support its own outer layers which will be gradually ejected in the form a spectacular '*planetary nebulae'*, blowing away the remnants of the solar system. As a *'white dwarf'*, all that will remain of our Sun during its final years of existence will be a cooling core which will simply fade into oblivion.

The Sun however is not the only star to have ever presented a serious threat to life on Earth. The deaths of other nearby stars in the form of *'supernovae'* can also have a dramatic effect on earthly life. Indeed it is widely postulated that Earth's first great mass extinction event *(at the end of the Ordovician period some 443 million years ago)* was initiated by a '*supernova'*.

There are several kinds of supernovae, which are generally categorised into two types according to their characteristics. *'Type **I**'* supernovae result from double star systems *(novae)* where a growing red giant encroaches upon the stronger gravity field of an older white dwarf star. Feeding from material drawn from the larger star, the density of the neighbouring white dwarf increases, causing nuclear fusion to periodically restart. A small majority of supernovae *('Type II')* result from the deaths of high-mass stars *(generally above eight times the size of our own Sun)*. Unable to support its own mass, such a dying star will undergo several waves of expansion and collapse, each time fusing increasingly heavier elements within its core. If the star is large enough it will eventually produce high enough core temperatures and pressures to fuse silicon atoms into iron. At this point fusion begins to absorb energy rather than release it, leading to a sudden gravitational collapse of the core into a neutron star, pulsar or *(in the case of a extremely massive 'hypernova')* even a black hole. The outer layers of such a star are blown off in an unimaginably large explosion which produces massive shock waves, thrusting an expanding shell of gas and dust outward ~ enriching the interstellar medium with heavier elements.

Supernovae are most commonly triggered by the sudden shutdown of a star's fusion cycle or *(in the case of binary systems)* the re-ignition of nuclear fusion through material taken from a companion star. They typically radiate more energy in a few hours than our own Sun will during its entire life as a main sequence star, and often outshine their entire host galaxies. In terms of their damaging effects to life on Earth, nearby supernovae can emit harmful gamma ray bursts that could seriously deplete the ozone layer. By weakening the upper atmosphere, such bursts expose our fragile biosphere to deadly solar and cosmic radiation. The 'danger zone' around a typical supernova is approximately a hundred light years, and thankfully no such stars are presently believed to exist near enough to effect earthly life in the near future. There are of course many thousands of stars within a hundred light year radius of Earth and, though most have already passed their red giant stage, an unexpected stellar explosion is always a possibility.

Human civilisation constitutes but a blip in universal time, yet many thousands of supernovae have occurred during our brief existence here on Earth. Nonetheless a supernova event has not been seen in our galaxy for over four centuries. The first one to be observed in recorded history exploded in 185**CE**, and references to this 'new star' can be found in Roman and ancient Chinese literature. Later given the name ***'SN185'***, the display is believed to have resulted from a Type **I** supernova which exploded around 3000 light years away. Other celestial explosions, now known to have resulted from supernovae were recorded in 1006, 1054, and 1181; the first two of which were actually visible in daylight at certain latitudes.

Originally recorded by Chinese and Arabic astronomers ***'SN 1054'***, for example, was a Type **II** supernova that exploded some 6300 light years from Earth, and its remnants can still be seen today as the ***'Crab Nebula'***. An expanding shell of gas over eleven light years wide, this spectacular nebula has a comparative luminosity which far exceeds that of our own Sun. At its centre lies what remains of its progenitor star, the ***'Crab Pulsar'*** ~ a collapsed core with a diameter of a mere eighteen miles that spins on its axis at just over thirty revolutions-per-second.

Two supernova events were also documented at a time when modern science was in its infancy. The first of these in 1572 occurred some 7500 light years away and was observed by a number of renowned astronomers including **'Wolfgang Schuler'**, **'Francesco Maurolico'** and **'Tycho Brahe'**. ***'SN 1572'*** played an important role in the new 'Age of Reason' by contradicting religious dogma of the time and proving that the Universe was ever-changing. Three decades later ***'SN 1604'*** *(at around 20,000 light years away)* became the last supernova to be observed in our own galaxy, and was notably studied by eminent German astronomer **'Johannes Kepler'**.

All of these supernova events occurred before the invention of the telescope in 1608. With today's powerful telescopes however the night sky can be seen in much greater detail, and a number of supernovae have been observed in galaxies other than our own Milky Way. The closest of these, in 1987 was seen to explode some 169,000 light years away in the nearby ***'Large Magellanic Cloud'***; a smaller companion galaxy. Like the supernovae observed at the turn of the 17th century *(which actually exploded well over 100,000 years later)*, ***'SN 1987A'*** contributed to our understanding of the Universe; this time giving us greater insight into the behaviour of the elusive *'neutrino'* ~ an elementary particle that permeates everything in our physical dimension. In 2006 came the appearance of the most energetic supernova so far observed ~ ***'SN 2006gy'***. Emanating from the distant galaxy ***'NGC 1260'*** which lies some 240 million light years away, this '*hypernova'* was far more powerful than any typical supernova explosion. Whilst such displays have captivated stargazers throughout the centuries, due to their distance however, none have had such a profound effect as the prehistoric supernova that directly preceded the development of vertebrate life on Earth.

Although a supernova event has not been recorded in our galaxy for over 400 years, many stars have the potential to produce a 'local' supernova over the next few centuries. Lying some 11,600 light years from Earth in the northern celestial hemisphere, for example, lies ***'Rho Cassiopeiae'*** ~ a yellow hypergiant whose magnitude has varied considerably over the years. Meanwhile, in the southern celestial hemisphere can be seen the super-massive variable star ***'Eta Carinae'*** which lies around 8000 light years away. In terms of size, both stars are in the region of 150 solar masses and have diameters in excess of 450 times that of our Sun. Moreover they are two of the most luminous stars known. Rho Cassiopeiae is *(for now)* approximately half-a-million times brighter than the Sun, whilst dramatic variability has been recorded in the apparent magnitude of Eta Carinae since it was first catalogued by British astronomer **'Edmond Halley'** in 1677. Indeed this star has held a particular fascination for astronomers over the centuries, and is believed to be on the verge of exploding as a potential massive supernovae. When it eventually blows, Eta Carinae is expected to explode with much the same ferocity as the distant hypernova observed in 2006, radiating in excess of 500 billion times as much energy as the Sun for several weeks before fading into obscurity.

Other equally plausible supernova candidates include ***'VY Canis Majoris'*** the most massive star known in our galaxy. A red hypergiant that lies approximately 5,000 light years away, **VY** Canis Majoris is widely anticipated to turn supernova over the next two millennia. Then there's the red supergiants ***'Antares'***, ***'Betelgeux'*** and ***'Spica'*** all of which lie just a few hundred light years from Earth and are easily visible to the naked eye. Every one of these stars are vast in size *(the largest would extend beyond the orbit of Saturn were it placed at the centre of our own solar system)* and all would dramatically brighten the night skies should they explode. Perhaps the most threatening however is not a large star at all. Although it is not expected reach critical mass for several million years, the closest of all potential supernova progenitors is the binary system ***'IK Pegasi'*** which, at 150 light years away, consists of an interacting white dwarf and an ageing main sequence star.

There is no doubt that a nearby supernova event would cause irrevocable damage to our living Earth. One in close enough proximity would subject the planet to intense cosmic radiation and could even induce chemical recombination of atmospheric gasses ~ effectively poisoning our breathable atmosphere. However the probability of such an event occurring in the near future is extremely low. Yet supernovae are not the only sources of galactic paroxysm. Harmful gamma ray bursts are also known to emanate from other types of stellar explosion. *'Super-magnetic neutron stars' (or 'magnetars')*, for example, can also produce immense celestial explosions. These are extremely dense, fast spinning neutron stars that have already undergone a supernova stage, but have not quite collapsed in to black holes. Core remnants of dead supergiants, magnetars exert exceptionally strong magnetic fields which actually stretch constituent atoms, causing the stars to elongate along their axes. When such a field snaps it releases highly condensed superheated gas trapped within the star's magnetosphere, creating intense flares that emit high energy radiation ~ often with as much force as any supernovae.

The 'last hurrah' of stars that have already died in spectacular supernova, several of these *'starquakes'* have been recorded since the first one was discovered emanating from the Large Magellanic Cloud in 1979. The most intensely scrutinised of all was observed in 2004, some 50,000 light years away on the far side of our own galaxy. When ***'SGR 1806-20'***, a comparatively small magnetar exploded it released more energy in a second than our own Sun emits in six million years. Yet at approximately 12 miles in diameter, the star was much the same size as Mars' larger moon ***'Phobos'***.

The most intense of all gamma ray bursts are believed to result from another type of stellar explosion. *'Quark novae'* themselves result from the collapse of particularly massive, rapidly rotating neutron stars, and produce amongst the most energetic explosions possible in our physical Universe. Indeed one of the most luminous cosmic events ever recorded *(a gamma ray burst detected in 1999)* most probably resulted from a quark nova. Emanating from a distant galaxy some nine billion light years away, ***'GRB 990123'*** was so huge that the accompanying optical flash would actually have been visible for a few seconds to anyone looking through a pair of binoculars in the right direction. Like similar gamma ray bursts, its progenitor neutron star would have spun so fast that the velocity of neutrons at its poles approached the speed of light, creating relativistic shock waves which caused the star to spontaneously collapse ~ releasing unimaginably huge amounts of energy. Once 'stabilised', gravity will have forced the star's composite neutrons into their constituent quarks, and all that kept it from collapsing further would have been surface tension.

Such explosions are so violent that they even have the capacity to obliterate a considerable part of a star's host galaxy. The resulting super-dense *'quark star'*, can be considered to be an intermediate state between a neutron star and a black hole. It is not dissimilar to a giant subatomic particle, containing several solar masses in a body approximately the size of ***'Uluru'*** *(or 'Ayers Rock')* in central Australia.

iii.

***(Unearthly threats:** Galactic anomalies)*

We live in a dynamic, ever-changing Universe. Our Earth orbits the Sun at a velocity of eighteen miles-per-second, whilst the Sun orbits the centre of our galaxy at around 135 miles-per-second. Astoundingly the Milky Way galaxy itself is believed to be moving outwards in space at a rate of approximately 375 miles-per-second. In these terms, our own planet covers a distance in 'open space' of over 32 million miles every day ~ the equivalent of travelling the perihelion distance to Pluto roughly every three months.

At around 100,000 light years in diameter, and containing some 400 billion stars, our home galaxy is truly massive. Looking towards the galactic plain on a clear night, it can be seen as a 'milky' haze straddling the sky above. In comparison our own planet is totally insignificant. To give an idea of comparative size; if the entire solar system were hypothetically reduced to an inch long, the main disc of the Milky Way itself would still stretch some 750 miles.

Although they may not present a direct threat to the solar system, our closest stellar neighbours are indeed very interesting. There are around 53 stars within fifteen light years of Earth, the closest known of which is the red dwarf ***'Proxima Centauri'***. At some 4.2 light years away this much older star is a little larger than Jupiter, and has such a low luminosity that it cannot be seen with the naked eye. However it is far from being dead, with magnetic convection causing it to occasionally flare to a higher magnitude. The fourth nearest star, ***'Barnard's Star'***, is another red dwarf which is currently around six light years from us. However it is hurtling towards our Sun at a phenomenal speed and in around another 9000 years time will be closer than Proxima Centauri. Perhaps the most spectacular however is the red dwarf ***'Gliese 710'*** which, although currently some 63 light years away, has a radial velocity that will bring it to within a light-year of the Sun's own gravitational sphere of influence. Although this will not happen for further 1.4 million years, the encounter with Gliese **710** has the potential to perturb the orbits of outer-solar system objects and give rise to new comets.

Yet, with a vast majority of stars in our galaxy forming binary or multiple star systems, it is not beyond the realms of possibility that another, as yet undetected, star lies even nearer. The relative orbits of binary stars can vary from anything between a few million miles to over a light year apart, and it has been theorised that an older brown dwarf lurks somewhere within our Sun's distant gravitational influence. Indeed it has been suggested that the orbit of a 'massive solar companion' *(nicknamed **'Nemesis'**)* periodically disrupts the outer reaches of our solar system, causing a new generation of comets to rain in on the planets every 26 million years. Such a theory could also account for the perceived regularity of extinction pulses here on Earth.

Many kinds of cosmic upheaval could have a catastrophic effect on life on Earth and not all involve massive explosions or collisions. Our galaxy is filled with a varying concentration of largely ionised gas and dust and, for the past five million years or so, the Sun has been passing through a cavity in this dilute 'soup' of interstellar particles. Known as the ***'Local Bubble'***, it is an elliptical region of space several hundred light years across, within which the interstellar medium is far more diffuse. Intersecting the galactic plain, and conjoined to other 'bubbles', the Local Bubble is the likely result of a nearby supernova having blown aside the surrounding interstellar medium, and it has shielded Earthly life from severe interstellar winds for several million years.

Yet its interior is not completely free of cosmic hazards and, although the bubble wall is approximately 190 light years away, for the past 60,000 years the Sun's galactic passage has taken it perilously close to a thirty light-year sized wisp of hot gas within it called the ***'Local Interstellar Cloud'***. At its edge, this *'local fluff'*, as it is sometimes known, is several billion times less dense than our own atmosphere and is easily deflected by the Sun's magnetic field. However a mere hundred-fold increase in density would begin to overwhelm the solar wind in the outer solar system edge exposing the furthest planets to the galactic environment. Should the Sun encounter an even denser region of interstellar gas, it has the potential to compress the heliosphere to a point within the Earth's own orbit. Such an event would not just seriously diminish the power of the Sun, but would expose our atmosphere to a wall of high energy cosmic radiation and an influx of neutral hydrogen atoms would fundamentally alter its very composition.

Whilst the Milky Way begets a myriad of fascinating and dangerous scenarios, beyond it lies even greater wonders, some with the potential to bring about unimaginable changes to our entire galaxy. One such example is a massive cloud of hydrogen that is hurtling towards the Milky Way at around 150 miles-per-second. Currently some 40,000 light years away, ***'Smith's Cloud'*** as it is named, is in excess of 11,000 light years long and contains more hydrogen than a million Suns. Set to collide with the Milky Way in around 20 million years, this huge bank of gas will invariably set off enormous shock waves as it interacts with the interstellar medium, leading to the formation of volatile new stars.

In around another four billion years ***'Andromeda'***, a large neighbouring galaxy *(and one of the few 'blueshift' bodies)*, is also likely to merge with our own. Currently at some 2.5 million light years away, and containing somewhere in excess of a trillion stars, Andromeda is nearly twice as massive as the Milky Way, and the two galaxies are travelling towards one another at around 130 miles-per-second. Were humanity to survive for the next four billion years, the ensuing galactic mayhem would completely alter our view of the night sky. Indeed the convergence would possibly destroy our own dying Sun, although it is unlikely to physically collide with another star. This is because, within their spiral arms, galaxies are mostly empty space, and even the most massive stars are minuscule in comparison to the vast expanses of surrounding interstellar void. However, whilst actual collisions here between stars would be comparatively few, most will undergo radical changes in orbit around the galactic nucleus, or more likely be drawn into orbit around the core of a new 'super-galaxy'.

One major consequence of a galactic collision is that most stars will at least encounter the gravitational fields of others, in many cases dramatically affecting their life cycles. Although it is just a medium-sized star, the gravitational influence of our Sun, for example, reaches nearly 1.5 light years ~ far beyond the outer boundary of our physical solar system or heliopause *(the point at which the solar wind is subsumed by the interstellar medium)*. Whilst gravity is the weakest of the four fundamental forces, it has by far the longest range. At such great distances its influence will cause many stars to undergo dramatic shifts in their galactic orbits, and a resulting super-galaxy of *(largely)* dying stars will invariably spawn even more multiple star systems. Indeed the relatively high percentage of binary systems in the Milky Way suggests that it has already encountered a galaxy of comparative size within its long history.

The climax of a future amalgamation of Andromeda and the Milky Way would be truly spectacular were we able to physically witness it. Close to the galactic core of a *'new Andromeda'* physical collisions between stars would be more abundant, and the creation of a new super-massive black hole would generate a gamma ray burst visible to observers in galaxies billions of light years away. Of course whilst the collision of galaxies presents potential destruction of mind-boggling magnitude, such a calamity is of no worry to us now!

iv.

***(Unearthly threats:** Interplanetary forces)*

The continuance of life on our fragile planet is at the mercy of any number of cosmic events and not all occur on a stellar or galactic scale. Indeed some of our closest celestial neighbours have the potential to catastrophically disrupt, or even obliterate, life on Earth.

One of the most unusual relationships in the solar system is that between our Earth and its 'oversized' Moon. Acting more like a binary system than a conventional planet and satellite, gravitational coupling of the two bodies has resulted in *'tidal acceleration'*; a process which both slows the Earth's rotation and accelerates the lunar orbit. Having become tidally locked to Earth *(i.e. one side permanently facing)*, the Moon continues to have a mutual, but diminished, effect on our planet ~ most evident in the tidal energy of our oceans. Although its gravitational pull is only 17% that of Earth's, the Moon is strong enough to create a 'tidal bulge' which is dragged ahead of its orbit by the Earth's faster rotation. Over several billion years, friction and inertia have served to decelerate this rotation, lengthening the Earth day by 23 microseconds a year, whilst the transfer of energy and angular momentum to the Moon pushes it into a faster and wider orbit which is currently receding at just under 1.5 inches every year.

Were it not for other cosmic forces at play, gravitational torque would eventually force the two bodies into a synchronous orbit, wherein an Earth day and lunar month would match. By the time that tidal locking permanently fixes the Moon in a distant orbit, it would be a much weaker force. Indeed the Moon would no longer stabilise the Earth's axial tilt, and increasingly wild swings in obliquity would bring about catastrophic changes in everything from Earth's climate to its magnetic field. However the time scale is too long for this process to complete before the Sun ends its lifetime as a main sequence star.

Yet the precarious dynamics of our solar system are not confined to our own Earth and Moon. Our neighbouring planet, Mars, and its innermost moon ***'Phobos'*** experience the opposite effect of *'tidal deceleration'* which pulls the satellite inward a little under an inch every year. At just over 16 miles across, Phobos is tiny compared to our own Moon and its effect on Mars' rotation is inconsequential. However, because it is in such a low equatorial orbit *(a mere 5,800 miles above Mars)*, its ultimate destiny *(unlike that of the Moon's)* lies within a much shorter time scale. The closest of all planetary satellites, Phobos is actually a captured asteroid, that will eventually be torn apart, forming a short-lived planetary ring around Mars before larger pieces impact the Martian surface. With Martian gravity about a third that of Earth's and its atmosphere less than 1% of the surface pressure of Earth, debris from a series of large impacts will invariably be thrown back into space. At its closest approach Mars is a mere 34 million miles from Earth which has a gravitational sphere of influence *(or* ***'Roche sphere')*** extending nearly a million miles, raising the possibility of meteoroids *(and even larger fragments)* heading towards us.

Fortunately the collision of Phobos with Mars is not due to occur for another 40 million years. Of more immediate concern however is the probability of a direct hit from an asteroid or comet originating from elsewhere in the solar system. Whilst most meteoroids burn up in our atmosphere as they descend, approximately 500 small meteorites strike Earth every year *(although it has been known for many thousands to land in a single 'chondrite' shower)*. Indeed, it is recognised, in the broadest terms, that an object the size of a car has the potential to flatten an entire city, whilst anything approaching half-a-mile in size would almost certainly cause a major extinction event. Thankfully, for humanity, the impacting of larger objects is much rarer. Nonetheless there is an estimated 5,000:1 chance of a large or medium-sized asteroid striking Earth at some time in 21st century.

Most asteroids that have been observed from Earth come from the ***'asteroid belt'***. Laying between Mars and Jupiter, objects in the main asteroid belt orbit the Sun *(and one another)* at a distance of between 186 million and 370 million miles from the star. Once more highly populated, this region of largely 'space rubble' constitutes a 'failed' fifth inner-planet which has been prevented from coalescing by Jupiter's pervasive gravitational pull. Today the combined mass of all of the asteroids in the main belt is somewhat less than that of our own Moon, nevertheless it still numbers around 200 million objects *(many thousands of which are larger than a mile across)*. The largest asteroid here is the interloping giant ***'Ceres'*** which, with an equatorial diameter of 605 miles, is now classified as a dwarf planet. Furthermore over half the mass of the entire main belt is contained within the four largest objects.

Although a majority of objects in the asteroid belt are comparatively stable, many have evolved elliptical orbits that cause them to pass within 1.3 astronomical units *(about 121 million miles)* of the Sun. These fall into a distinct class of celestial bodies known as *'near Earth objects' (or* ***NEO****s)* of which, by the second decade of the 21st century, around 6,000 had been catalogued *(including around 800 objects larger than half-a-mile in diameter)*. Whilst a number of **NEO**s are believed to be dead comet fragments, most come from the asteroid belt, having been involved in a collision or jarred from their original orbits through gravitational perturbation with Jupiter. Many of these regularly cross the Earth's orbit.

These *'near Earth asteroids'* are divided into three families *(the* ***'Amors'***, ***'Apollos'*** *and* ***'Atens')*** with only the Amors in orbits that do not actually intersect the Earth's. Measuring nearly 26 miles in diameter, the largest known **NEO** is the Amor asteroid ***'1036 Ganymed'*** *(although there remains the possibility of yet larger undiscovered ones)*. Discovered in 1924, this large *'Mars-crosser'* can come within 22 million miles of Earth. The largest of all known *'Earth-crossing asteroids'* was discovered in 1972. ***'1866 Sisyphus'*** is a 6 mile-wide Apollo asteroid whose dimensions make it of similar size to the famous 'Chicxulub object' which brought about the extinction of the dinosaurs. In 1986 came the discovery of ***'3753 Cruithne'***, a particularly curious solar-orbiting object. A three mile-wide Aten asteroid, Cruithne has settled into an orbit which is synchronised with that of our own planet. Although its closest annual approach is no less than 7.5 million miles *(about thirty lunar distances)*, its own orbit is not as stable as our Earth's and the slow process of gravitational perturbation could potentially bring it nearer over the next few million years.

A smaller, but somewhat closer encounter, is that with the 1000ft wide Apollo *'Earth-crosser'* ***'4581 Asclepius'***. In 1989 it came within 375,000 miles of Earth, passing through a shared point in our solar orbit just six hours earlier. Had it actually collided with Earth, Asclepius would have no doubt brought about considerable regional devastation. The closest approach of all known *'potentially hazardous asteroids' (PHAs)* in the current century occurred in 2004 when the two mile long Apollo asteroid ***'4179 Toutatis'*** passed within four lunar orbits of Earth. Any impact with this object would almost certainly destroy virtually all life on the planet.

There are likely to be numerous near misses *(and even strikes)* in the coming millennium, though few *(if any)* will involve large objects. However several larger asteroids that are due to make close passes of Earth have already been identified. ***'99942 Apophis'***, for example, is a 1150ft. long Aten asteroid that crosses the Earth's orbit with unnerving regularity. Travelling at just under twenty miles-per-second, Apophis is due to make close approaches in 2029 and 2036; the first of which is expected to bring it within some 22,000 miles of Earth *(beneath the orbits of manmade geostationary satellites)*. Given its inclination, this pass could significantly alter its orbital trajectory, making subsequent approaches harder to predict. At worst it has the potential to bring Apophis into orbital resonance with the Earth, bringing about a greater probability of future impacts. The most threatening of **NEO**s so far catalogued though, is an Apollo asteroid designated as **'*1950 DA*'**. With a mean diameter of over three-quarters of a mile, **1950 DA** was, at the turn of the century, predicted to have a one-in-300 chance of impacting Earth in 2880. Although its threat has since been downgraded, the force of such a strike, were it to happen, would be equivalent to the detonation of 44,800 megatons of **TNT**, no doubt causing a major extinction event.

It is not only larger objects, however that pose an ever-present threat to Earthly life. Smaller asteroids *(categorised as 'meteoroids' below 164ft. [50 metres] across)* can also cause considerable localised damage should they impact the planet from a retrograde orbit. Of course we encounter meteor showers with predictable regularity, the largest of which can create screeching fireballs in the night sky. Yet not all visible meteors result from the fine residue of comets whose paths have crossed Earth's orbit. Particularly close encounters with stray meteoroids are not infrequent, with perhaps the most famous of these *'Earth grazers'* passing a mere 35 miles over North America in 1972. ***'The Great Daylight 1972 Fireball'***, as it was named, was a very small Apollo asteroid with a low inclination and, as it passed through the mesosphere, presented a spectacular sight to observers from Utah to Alberta. Yet the object itself was no larger than 30ft. across. Moreover by the time it had left the atmosphere, its close encounter with Earth, had considerably reduced its mass and velocity, significantly altering its orbital inclination.

An acute scientific awareness of the dangers posed by asteroids and other space fragments that stray within the vicinity of Earth's orbit has only developed in the past few decades. As a result, methodical documentation of new asteroids and careful monitoring of known **NEO**s really began in the 1980's. Whilst only two subsequent Earth grazers have been observed, numerous 'near misses' have since been recorded, with satellites sensors detecting an average of forty high altitude blasts every year caused by boulder-sized meteoroids skimming the upper-atmosphere.

The close approaches of many small asteroids have also been observed, typified by two large Aten meteoroids discovered in 2004. At 100ft. in diameter, ***'2004 FH'*** passed within some 26,000 miles of Earth and, even if it was on a collision course, its size and low inclination would have made it comparatively harmless. Less than two weeks later a 20ft. long meteoroid named ***'2004*** FU_{162}***'*** came within 4,000 miles of Earth but, it too it would have most likely exploded in the mesosphere had it come much closer.

Of course, regardless of size, a vast majority of asteroids in the solar system pose no immediate threat at all to Earthly life. Indeed over the course of some four billion years, the most dramatic events within the asteroid belt have already been played out, and today's comparatively sparsely populated belt is much more stable. Nonetheless, the orbital trajectories of smaller objects within the main belt itself are continually altered by both inter-asteroid collisions and the irresistible gravitational pull of Jupiter, creating a complex interplay of orbiting bodies.

Besides distributing asteroids according to their synchronised motion *(or orbital resonance)* with the gas giant, Jupiter's enormous gravitational influence has spawned numerous families of asteroids. Perhaps the least threatening of all are the ***'Trojan asteroids'*** which 'clump together' in the same stable orbital path of Jupiter *(and Neptune)* at a distance exactly 60° ahead and behind it. Amongst the least stable are the Earth-crossing ***'Alinda asteroids'*** which have evolved orbital resonance with both Jupiter and Earth. Including the potentially hazardous asteroid Toutatis in their numbers, the increasingly eccentric orbits of the Alinda's cause them to make repeatedly close approaches to Earth every four years. Also unique to Jupiter are the ***'Hilda asteroids'***; an unusual family of objects which have become caught in an 'extreme' orbital resonance with the massive planet. Its significant gravitational pull has effectively dragged these asteroids into a 'triangular' orbit which experiences centripetal acceleration towards three libration points along Jupiter's own orbit. Skirting both the outer main belt and Trojan asteroids, the Hilda's are a major progenitor of new **NEO**s.

Further out in the solar system, lies a distant conglomeration of trans-Neptunian objects orbiting beyond the last gas giant. Called the ***'Kuiper belt'***, it is collectively several hundred times more massive than the main asteroid belt between Mars and Jupiter. Yet, because it covers a region between 2.8 billion and 4.6 billion miles from the Sun, far fewer objects within it have so far been identified. A vast majority of the estimated six billion or so Kuiper belt objects are 'small solar system bodies' less than 1000ft. wide, although several hundred thousand extend over 30 miles in diameter making them large enough to be classed as medium-sized planetoids or large comets. Planetoids several hundred miles in diameter *(of comparable size to **'Pluto's largest moon 'Charon')*** number over a thousand and include objects such as ***'90482 Orcus'***, ***'50000 Quaoar'*** and ***'20000 Varuna'***. With diameters measuring over a thousand miles, the largest objects in the Kuiper belt however can be classified as dwarf planets. These include Pluto *(the first Kuiper belt object to be discovered)* as well ***'Eris'***, ***'Haumea'***, and ***'Makemake'***.

Largely composed of rock, ice and other frozen volatiles, most Kuiper belt objects are of similar composition to comets. Yet, regardless of size, almost all are distinctive in that they have evolved some kind of orbital resonance with Neptune. Indeed due to its distance from the Sun, Neptune has a far greater Roche sphere than even Jupiter, and its effect on the outer solar system is significant. Whereas two thirds of known Kuiper belt objects follow circular orbits within a main 'doughnut shaped' ring, either side of this *'classical belt'* most have highly eccentric orbits.

At the inner-edge lay the comparatively large ***'Plutinos'*** *(including Pluto itself)* which regularly cross the path of Neptune at a safe distance from the giant planet. Like the relation between the Hilda asteroid family and Jupiter, the Plutinos have evolved a '2:3 mean motion resonance' with Neptune which prevents any possibility of collision and holds them in relatively stable orbits. Neptune's largest moon ***'Triton'***, however, is believed to be a captured inner-Kuiper belt object whose trajectory was perturbed by the gas giant before it could establish a stable resonant orbit. Other planetoids originating from the inner-Kuiper belt are not so stable. These include the ***'Centaurs'*** ~ icy planetoids which have been flung inwards by Neptune, most of which cross the paths of the other the gas giants. Because they experience orbital perturbation from two or more of the giant planets, they are unable to establish orbital resonance with any one, and regularly alter their chaotic orbits. By percentage these can be amongst the most menacing objects to Earth.

Beyond the outer-Kuiper belt lies a region called the ***'scattered disc'***. Here it is sparsely populated, again with larger planetoids, some of which are so distant that their orbits are completely detached from Neptune and its giant sisters. With a diameter of approximately 920 miles, ***'90377 Sedna'*** is the most distant large planetoid known, although its status as a dwarf planet has yet to be confirmed. Sedna's highly elliptical, 12,000 year orbit has a perihelion that skirts the outer-Kuiper belt *(making its closest approach at just over 7 billion miles from the Sun)* whilst its aphelion reaches over 90 billion miles into the void. The scattered disc however also contains objects whose orbits are eccentric in the extreme. These include ***'2000 OO_{67}'***; an icy planetoid *(and a probable Centaur)* around 36 miles in diameter, whose orbit crosses the path of Neptune yet extends to almost 100 billion miles *(over six light days)* from the Sun, Another extreme trans-Neptunian object is the 140 mile-wide ***'541132 Leleākūhonua'*** whose aphelion is over 2100 astronomical units *(almost 200 billion miles),* making it one of the most distant objects currently detectable within the known solar system. Only certain 'long-period comets' travel this far out *(and they are of course only observable when they near the Sun).*

Far beyond even the reaches of Leleākūhonua and its distant companions lies the postulated ***'Oort cloud'***, an enormous reservoir of 'dormant' comets whose outer boundary marks the furthest extent of the Sun's gravitational influence. A remnant of the Sun's proto-planetary disc, the Oort cloud is a huge sphere of thinly dispersed objects extending from around 4 light months to 1.6 light years *(between 2 trillion and 9 trillion miles)* from the Sun. Although sparsely populated, the combined number of objects here is so great that it collectively amounts to several Earth masses. Indeed the familiar planetary solar system is minuscule by comparison,

Comprising frozen matter left over from the formation of the solar system *(as well as debris and celestial flotsam gathered from the interstellar medium)* the Oort cloud is home to over a trillion slow-orbiting comet nuclei, many of which have near circular orbits. Most have evolved only slightly different orbital velocities and trajectories around the Sun, and compared to planetary orbits, almost 'hang' in space. Because they are weakly bound to the Sun as it orbits the galaxy, they can experience orbital perturbation from a variety of extra-solar influences. Indeed the Oort cloud is exposed to near encounters with other local star systems *(and their own Oort clouds)*, interloping comets, and even the galactic tide which can readily compress it. Resulting comets can be thrown out into the interstellar void or conversely be forced inward towards the Sun and planets.

Comets themselves are generally far less predictable than asteroids, and some can remain undetected until just a few days before their closest approach. The main differences between comets and asteroids are composition, size, and origin. Unlike asteroids *(which are largely composed of silicate minerals or iron oxides)*, comets contain water ice, frozen gasses, and a variety of organic compounds, often encased in a crust of compacted dust particles. As they approach the inner-planets, solar radiation, begins to vaporise their frozen interiors which break through the surface to form a coma *(or primitive atmosphere)* around the nucleus. Closer to the Sun, solar winds blast the coma from the main body of the comet forming their distinctive tails of dust and ionised gas. A vast majority of comet nuclei are comparatively small, averaging just a few miles across, although the largest extend over 100 miles in diameter, and can exhibit tails that stretch over 150 million miles. In addition, all comets originate from the Oort cloud *(although some have migrated to the Kuiper belt and beyond)* and, in cosmic terms, their highly eccentric orbits make them relatively short-lived.

Based on their orbital characteristics, comets fall into four main types. The *'Jovian comets'* have the shortest orbital periods, often passing between Jupiter and the Sun once or twice a decade. These include comet ***'Tempel 1'*** whose 5½ year orbit makes it a faint but frequent visitor to our night skies. Comets that revisit the Kuiper Belt every orbit are known as *'short-period comets'* and can take up to 200 years to reappear ~ although a majority have orbital periods of between ten and twenty years. Perhaps the best known of these is ***'Halley's Comet'***. which has an orbit of just over 75 years *(with its next visit to the inner solar system due in 2061)*. *'Long-period comets'* meantime can take anything from 200 to a million years to orbit, returning to the Oort cloud and a state of deep freeze if they survive their solar pass-by intact. A good example is comet ***Hale-Bopp'*** which returns once every 4026 years. Some *(known as 'single-apparition comets')* may even have escape orbits ~ passing the Sun just once before being catapulted into interstellar space.

There is evidence to suggest that prehistoric comets have impacted the Earth on many occasions. Because they often consist of water ice and organic molecules, it is speculated that they may even be the progenitors of life on Earth. Indeed around 3.8 billion years ago, during what is referred to as the *'late heavy bombardment'*, the inner-planets were at the mercy of a far less stable solar system. At approximately the same time, our 'proto-Earth' had developed shallow seas, and primitive life gained its first foothold on the new planet, giving rise to the erroneous theory of *'panspermia'*.

In recorded history, comets have passed as close as 1.4 million miles to Earth and their unpredictability means that even with modern satellite technology, we only become aware of many comets, at most a few weeks in advance of their arrival. Often travelling at speeds in excess of 185 miles-per-second, comets or comet fragments collide with our planet roughly once every 2000 years. Most of course will not hit the Earth, although we can expect an exceptionally bright comet to appear on average at least once a decade. However they have had a much greater impact on the human psyche.

A reminder that we do not live in a calm orderly Universe, in ancient and medieval times the appearance of comets were regarded with great reverence. For millennia they were simply fiery signs that confirmed the presence of the gods *(or god)*, and were most commonly seen as omens of impending doom. Indeed they became the harbingers of everything from plague, famine and death to victory or defeat in battle. All that was to change with the scientific revolution of the 17th century. The reappearance of ***'Kirch's Comet'*** in 1681 enabled renowned English physicist **'Isaac Newton'** to confirm *'Kepler's laws of planetary motion'* and formulate his theory of *'universal gravitation'*. The most famous of all periodic comets was discovered the following year by Newton's colleague, English astronomer **'Edmond Halley'**, who accurately predicted its return.

Yet even with the benefit of scientific rationale, comets still hold a religious or spiritual significance for many people. For much of 1996 and '97, Hale-Bopp was visible to the naked eye, and became one of the brightest comets of the 20th century. Measuring around 25 miles in diameter, it passed within some 122 million miles from Earth, and displayed a staggering 56 million mile-long tail. Despite our clear understanding of such phenomenon, so spectacular was the sight that it drove 39 members of *'Heaven's Gate' (a pseudo-religious cult in California)* to mass suicide, believing death would release their souls and enable them to board an alien spaceship concealed within the comet.

The first great comet of the 21st century, ***'Comet McNaught'***, reached naked eye visibility a mere ten years later, becoming almost as spectacular. None however compare with the display put on by ***'Shoemaker-Levy 9'***, a short-period comet which impacted Jupiter's southern hemisphere in 1994. Having been captured in a degrading orbit around the gas giant in the early 1970's, Shoemaker-Levy 9 was torn apart by tidal forces during a close approach in 1992. By the time it collided, the comet had already broken up into over twenty discernible pieces, the largest of which were still over a mile across. The impact generated a series of explosions, the greatest being equivalent to the detonation of 6 million megatons of **TNT**. This was the first time two extraterrestrial solar objects had been seen to collide, generating great interest in the comet's demise. Had it hit actually hit Earth instead, Shoemaker-Levy 9 would have created the biggest impact for 65 million years and no doubt been a major extinction event.

Over the past few decades mankind has become increasingly aware of the dangers posed by asteroids and comets, and the potential of any impact to seriously affect life on Earth. Asteroids, comets and meteors are remnants of a distant time in the long history of our solar system and, although their numbers may have dwindled in the last four billion years or so, they still present a very real threat to our own continued existence.

For billions of years the planets and moons of our solar system have been bombarded by millions of objects. Whilst Jupiter and the other gas giants may not show the scars of impact, the rocky planets most certainly do. Of all the inner-planets Mercury has the most heavily cratered surface. Its proximity to the Sun *(with its phenomenal gravitational pull)* has invariably put Mercury in the path of more asteroids and comets than any other rocky planet or moon. Visible impact craters are also plentiful on our Moon, yet they are not immediately noticeable on Earth because our own living planet is constantly regenerating, Plate tectonics, along with the effects of weathering and erosion, heal the scars of asteroid and comet impact, hiding evidence of past collisions. Nonetheless over two hundred natural impact craters have so far been identified on Earth.

Millions of tiny meteoroids enter our atmosphere every year. A vast majority, however, are no larger than 'scree-sized' rocks or small boulders, and most are vaporised in the upper-atmosphere. Meteoroids smaller than grains of sand can often be seen in the night skies as *'shooting stars'* with their distinctive long glowing tails emanating from their points of entry. This is the visible result of their very atoms being stripped of electrons as they pass at tremendous velocity through the magnetosphere. Meteor showers occur with predicable regularity as the Earth's orbit around the Sun takes it through particle streams ~ fine debris left by the paths of periodic comets. Whilst most meteoroids put on a mesmerising but silent display, larger objects can reach lower levels, passing overhead as spectacular *'fireballs'*.

Of the many thousands of objects that actually hit the Earth each year, most fall harmlessly as small meteorites, often striking the oceans or sparsely populated areas of land. However, given that the average size of a natural impact crater is three miles across, collisions with larger objects most certainly occur with unnerving regularity. Any impact that results in a crater of this size would no doubt cause considerable damage, releasing around the same amount of energy as a 10,000 megaton bomb *(or more explosive power than all of world's nuclear arsenals combined)* Moreover a number of 'potentially hazardous asteroids' larger half-a-mile in size have passed perilously close to the Earth in recent history.

In terms of the continuance of life on Earth, the presence of Jupiter has proven to be somewhat of an enigma. With its huge mass and pervasive gravitational field, the gas giant is widely regarded to have saved our planet from numerous collisions in the past. Yet it does not simply attract cosmic debris that might otherwise impact Earth. It can also alter the trajectories of stray asteroids and comets, drawing them into irregular or unstable orbits that pass closer to the vulnerable inner-planets *(the creation of the Centaur asteroids being a case in point)*. Furthermore it is Jupiter's enormous gravitational influence which has graded the size and composition of asteroids within the main belt, kept them in a state of flux, and prevented them from forming a stable fifth inner-planet. Indeed the existence of Jupiter is very much a mixed blessing to Earthly life.

Computer models have suggested that a major collision occurred within the asteroid belt around 160 million years ago, sending huge fragments of rock and ice in all directions. Some of these 'shards' developed degenerative orbits around the inner-planets, giving rise to a new family of asteroids *(known as the **'Baptistinas'**)*. As a result, over the following 100 million years or so, the number of impacts rose considerably and *(like the other inner-plants)* our own Earth and Moon were subjected to comparatively regular bombardment. Indeed one of the most spectacular features on the Moon, the 50 mile-wide ***'Tycho crater'***, was probably caused by one of these asteroids impacting its Southern Highland region around 108 million years ago. A larger asteroid from this cosmic upheaval is believed to have struck the Earth ~ on the northern edge of the Yucatán Peninsular around 65 million years ago, and evidence remains of a large crater centred on what is now the Mexican town of Chicxulub. Partially forming an enormous submarine basin, at some 115 miles in diameter the renowned ***'Chicxulub crater'*** resulted from an object about six miles across slamming into Earth, and is widely believed to have been a decisive factor in the extinction of the dinosaurs.

There is no doubt that the impact of an object this size would have been a global catastrophe for prehistoric life. Yet there is growing evidence to suggest that the Chicxulub object may have been just one in a number of huge asteroid fragments to have struck Earth in a multiple impact event. Indeed it is more likely that it occurred during an elevated rate of impacts which lasted over several millennia and resulted from an encounter with the Baptistina asteroids. In addition to the discovery of smaller impact sites *(including the **'Boltyish crater'** in Ukraine, and the **'Silverpit crater'** in the North Sea)*, it has been postulated that the much larger ***'Shiva crater'*** *(a sea floor structure off western India some 300 miles in diameter)* resulted from the low inclination impact of a 26 mile-wide object plunging to Earth at around the same time. The largest collisions during the *'Maastrichtian extinction peak'* at the end of the Cretaceous period would have had far reaching effects, sending seismic waves around the globe, intensifying volcanic activity, choking the atmosphere with toxic gasses and creating perpetual night for many months at a time.

The Cretaceous extinction was by no means the first time that prehistoric life had been devastated by an extraterrestrial event. Indeed it has been hypothesised that geological anomalies in Antarctica and off Australia are the remnants of even larger impact craters which were created between the Permian and Triassic periods some

250 million years ago ~ precipitating the *'mother of all extinctions'*. The largest impacts can actually effect the tectonic processes of the planet itself, inducing other major extinction factors such as increased volcanism and sea-level change.

Whilst so-called 'mass extinctions' *(when over 50% of living species are wiped out)* are comparatively rare in Earth's long history, regional and localised ones are not. Of course not all extinction events can be directly attributed to asteroid or comet collisions, but the cyclic nature of their intensity over many millions of years points to a strong connection with celestial forces. Indeed it has been theorised that the regularity of extinction pulses coincides with blip in Sun's orbit of the galactic centre of the Milky Way or, more likely, with the orbital cycle of a particularly hazardous group of long period comets.

Since the demise of the dinosaurs 65 million years ago, at least two other extinction events *(35 million and eleven million years ago)* are known to have coincided with celestial objects colliding with our planet. Moreover the time between the great extinctions of prehistory was itself punctuated with smaller, regional extinction events every few thousand years. So regular is this occurrence that, using evidence based on fossil records, the average life span of any mammal species has even been determined. Were the future of the human race solely at the mercy of asteroids and comets, it has been calculated that our own species would have no more than another 2¼ million years left to exist.

The asteroid/comet hazard *(and its associated risk to civilisation)* is perhaps the smallest of our problems when compared to more pressing matters such as population explosion, global warming, pollution, exhaustion of natural resources, disease and war. However smaller, yet hugely destructive, asteroids collide with the Earth relatively often, and should one strike a heavily populated area, human civilisation would be turned on its head.

Perhaps the most familiar impact site on Earth is that near Winslow in northern Arizona. The 4,000ft wide ***'Berringer Crater'*** was made by a nickel-iron meteorite of around 150ft. in diameter colliding with Earth some 50,000 years ago ~ causing complete devastation for many miles around. There is evidence to suggest that other large impacts occurred over North America and Siberia during the prehistoric ascendancy of modern man. Indeed meteorite fragments have been found in the bones of mammals from both 35,000 and 13,000 years ago ~ evidence of events which would no doubt have seriously affected the regional environments of the time.

Early civilisation has also had to endure a number of damaging impacts. Studies of Arctic ice and ancient timbers have revealed that a serious global incident occurred at around **CE**540 ~ coinciding with start of the European Dark Ages. With volcanic activity largely discounted by the lack of sulphur in Arctic ice of this age, the most likely cause was an asteroid or comet exploding somewhere over the skies of the northern hemisphere. A massive air burst *(probably the equivalent of many atomic explosions)* would have liberated dust high into the atmosphere, markedly dimming the Sun's light and decreasing global temperatures by several degrees for a number of years. Indeed tree ring chronology dating back over the past 7500 years even appears to support stories of devastation within certain ancient chronicles and legends which were, until recently, regarded as complete mythology. With modern civilisation reaching every corner of the globe, an impact on a similar scale today would be a global catastrophe for humankind.

There have been a number of serious asteroid/comet encounters with Earth in modern history too. In 1863 a sizeable iron meteorite impacted the Ar-Rub' Al-Khali Desert south-west of Wabar in Saudi Arabia. Liberating at least as much energy as the 'Hiroshima bomb', its oblique angle of descent caused the object to leave three large craters ~ the largest being some 380ft. across. In 1908 a comet fragment of around 245ft. detonated over the remote Tunguska region in Siberia. Whilst being too small to cause an extinction event, the Tunguska object exploded with a force equivalent to 15 megatons of **TNT** *(or a medium-sized thermonuclear warhead)*, with much of its energy being converted to heat by atmospheric pressure. Whilst no human casualties were apparent, this encounter devastated an area of over 770 square miles, felling some 80 million trees.

Another significant event occurred in 1930 near Rio Curaca in the Brazilian rainforest, close to the Peruvian border. Exploding with a force of about ten Hiroshima bombs, the Rio Curaca event was repeated five years later when a similar-sized object detonated over the Rupununi region of British Guyana. In areas of such rich biodiversity as these, the localised extinction of some endemic species would have been inevitable. Even more recently *(though somewhat less damaging)*, in 2002 a 30ft object vaporised over the Mediterranean sea, creating an explosion equivalent in size to 26 kilotons of **TNT**. These events imply that dangerous collisions occur more frequently than once believed. Indeed there have been at least five 'medium-sized' impacts in the last century, and so far we've been fortunate that none have actually hit a populated area. However as urban growth continues, so the risk of an object destroying millions of human lives increases.

In the 1980's, asteroid/comet strikes and near misses began to be recorded in far greater detail. It has since become apparent that a 'Tunguska-sized event' happens about once a millennia, whilst an impact large enough to bring about a regional extinction occurs approximately every 100,000 years. In fact the past few decades have seen the discovery of several thousand new asteroids and comets moving around the Sun in highly elliptical orbits, raising our awareness of potential collisions considerably. Once discovered, the reappearance of most 'near-Earth objects' ***(NEOs)*** can be calculated with relative ease. However, being comparatively small, numerous factors can influence the orbital trajectories of these objects, making the dangers posed by their transient presence in our solar neighbourhood much harder to predict.

Asteroid '***99942 Apophis***', for example, is only just over a 1000ft. in diameter and its close approach in 2029 takes it through a minefield of space junk in 'high Earth orbit' ~ raising the chances of a collision in future returns. Given its size and velocity, if and when Apophis does one day impact Earth, it will do so with a force equivalent to some eighty Tunguska events. Moreover, new objects of similar size are continuously being discovered, many of which give little warning of their imminent arrival in our skies. In 2008, for example, the 800ft long asteroid ***'2007 TU24'*** passed within some

350,000 miles of Earth *(about 1½ times the distance of the Moon)*, yet it was only discovered two months before making its closest approach. Though currently much further away, like Apophis, **TU24** would bring about considerable damage to civilisation should it ever collide with our planet.

Whilst the United Nations, along with the **US** and other Western nations, have established specific 'impact alert plans', numerous independent and government-funded ground-based projects have been set up to detect and track new asteroids. These include the University of Arizona's ***'Spacewatch'***, the ***'Near-Earth Asteroid Tracking'*** program *(NEAT)* in Hawaii, and the hugely successful ***'Lincoln Near-Earth Asteroid Research'*** project *(LINEAR)*. Work at **LINEAR**'s initial observatory at Socorro, New Mexico officially commenced in 1996, and within its first ten years of operation some 220,000 new objects had been discovered ~ including over 2000 'near-Earth asteroids and comets.

As far as missions to specific asteroids and comets are concerned, in the same year that **LINEAR** got underway, the 'North American Space Agency' ~ **NASA** launched its ***'Near Earth Asteroid Rendezvous'*** *(or' **NEAR**-Shoemaker')* probe. The probe's primary mission was to investigate the 21-mile-long 'peanut-shaped', Amor asteroid ***'433 Eros'*** whose slowly degenerating orbit currently takes it to within 17 million miles of Earth. **NEAR-**Shoemaker proved to be an unexpected success *(the probe actually managed an unscheduled landing on Eros in 2001)*, and **NASA** embarked on a number of subsequent programmes. Launched in 1999, their unmanned ***'Stardust'*** spacecraft was primarily designed to collect and return dust samples during a flyby of comet ***'Wild 2'***. This three mile-wide, Kuiper Belt object had had its forty-year orbit dramatically reduced to six years following a close encounter with Jupiter in 1974 ~ bringing it into the realm of the inner-planets.

By the start of the new century, there was intense scrutiny of asteroids and comets, and various missions had gotten underway worldwide to investigate our smallest celestial neighbours. In 2003 the 'Japanese Aerospace Exploration Agency' ~ **JAXA**, launched its ***'Hayabusa'*** spacecraft which was designed to land on the quarter-mile wide Earth-crosser asteroid ***'25143 Itokawa'***, collect samples and return them to Earth. Although it managed to touchdown on the asteroid two years after its journey commenced, Hayabusa was plagued with failures, and its mission plan had to be changed several times. A year after the launch of Hayabusa, the 'European Space Agency' ~ **ESA** despatched its ***'Rosetta'*** spacecraft on an eleven year mission to investigate ***'67P/Churyumov-Gerasimenko'*** ~ a Jovian comet whose orbit is regularly perturbed by the gas giant. Having achieved enormous success with its ***'Giotto'*** probe *(which studied Halley's comet in unprecedented detail in 1986)*, **ESA** had high hopes for Rosetta, which released a lander onto the comet's surface before escorting it around the Sun in 2015.

It is **NASA** however that remains at forefront of asteroid and comet exploration. Launched in 2005, **NASA**'s ***'Deep Impact'*** mission comprised an unmanned spacecraft which carried a probe designed to impact comet Temple 1, enabling it to examine both its interior and exterior. Once the probe had successfully collided with the comet six months later, the mothership's trajectory was altered, enabling it to flyby another comet, *(**'Hartley 2'**),* in 2010. Unfortunately, three years later, communications with the craft were permanently lost. Another spacecraft, ***'New Horizons'***, was launched in 2006. New Horizon's mission objectives included a comprehensive study of Pluto and its moons in 2015, before continuing deeper into the Kuiper Belt to search for new objects in this distant and elusive region of the solar system. A little closer to home, in 2007 **NASA** launched its ***'Dawn'*** spacecraft ~ beginning an eight year mission to investigate the structure, composition and origin of the two largest asteroids within the main belt. By 2011 Dawn had orbited the 329 mile-long ***'Vesta'*** *(the brightest of all asteroids)* before moving on to study the dwarf planet Ceres *(by far the most massive object in the asteroid belt)* in 2015.

Since the launch of Dawn, a number of missions by various space agencies have been sent to study dozens of asteroids, including several that are classified as potentially hazardous. These include the '**CNSA**'s '***Chang'e 2'*** lunar probe *(which performed a successful flyby of '**4179 Toutatis'** in 2012),* **JAXA**'s '***Hayabusa2***' *(which successfully returned a sample of* '***162173 Ryugu'*** *in 2020),* and '**NASA**'s '***OSIRIS-REx'*** which departed ***'101955 Bennu'*** in 2021 *(having taken samples for detailed analysis)* before heading off to rendezvous with Apophis during its close approach to Earth eight years later. Besides equipping us with greater knowledge of the ever-present dangers that lurk within our solar system, the data provided by all of these craft have proven invaluable in understanding the physical evolution of our own planet.

As for Apophis itself, although it is highly unlikely to strike Earth during its next close encounter, its present orbit will eventually degrade with spectacular results. This menacing asteroid may one day collide with Earth or, equally plausibly, it could be consumed by Jupiter or the Sun itself. Current technology is simply incapable of determining whether or not Apophis will become the next major impactor to strike our vulnerable planet. However the natural hypothesis of a large asteroid or comet one day colliding with Earth is strong enough to suggest that it <u>will</u> happen again at some point in the future. Indeed, life on the planet is completely at the mercy of impact events, and the concept of a future asteroid/comet collision lies beyond logical supposition ~ it is a certainty.

Footnote

Whilst **NASA** and other international space agencies may be best equipped *(both financially and technologically)* to undertake asteroid/comet exploration, they are by no means the only institutions to contribute to the science. Independent funding and research is provided for numerous commercial and private ventures throughout the developed world. Indeed, so compelling are these dynamic celestial bodies, that an international competition to design a spacecraft to tag and track Apophis before its close encounter with Earth in 2029 attracted 37 entrants from around the globe. The focus for this event was the Pasadena-based ***'Planetary Society'***, which announced ***'Foresight'*** as the winning entry in 2008. Designed by Atlanta-based company ***'SpaceWorks Engineering'***, the Foresight craft was expected to launch in 2012 but unfortunately did not get beyond planning stage.

v.

*(**Terrestrial calamities:** Major earthquakes)*

Continental drift is the single-most important factor in the evolution of life on Earth. It determines the make up of terrestrial temperature zones, changes ocean currents, alters regional weather patterns and profoundly effects the global climate. The complex interplay of tectonic plates is responsible for opening and closing land bridges and seaways, allowing life to diversify into new regions of the planet. In turn it can introduce species to new competition, altering the very make-up of food chains around the globe.

Land masses move around the face of the Earth due to the underlying process of plate tectonics, where forces deep within the planet's interior cause its segmented surface to be continually recycled. Whilst the geological timescales involved in continental drift are far too great to be noticed in a single lifetime, over many thousands of generations its effect on Earthly life is profound. It can lead to the evolution of new species and induce radical alterations to existing ones. On a shorter timescale however tectonic activity can also be highly destructive ~ causing sudden, violent changes to the environment. It even has the capacity to bring about the extinctions of entire species in an instant.

The densest and largest inner-planet of the solar system, our Earth, has a mean diameter of 7,926 miles. Encased in a rocky silicate crust that is rich in oxides, the internal structure of the planet is chemically layered throughout. At its centre lies a spherical ***'inner core'*** around 1500 miles in diameter. Composed largely of an iron-nickel alloy, the inner core reaches temperatures in excess of 6500º**C**, but is kept solid by enormous pressures. It is surrounded by a liquid ***'outer core'*** some 1350 miles thick, which mostly comprises molten iron with a mixture of various lighter elements. This in turn is enveloped by the Earth's ***'mantle'*** ~ a highly viscous, graded layer of silicate-rich metal and igneous rock, approximately 1750 miles thick. Disparity between the faster rotating inner core and the mantle generates strong electric currents in the fluid outer core. It is this that causes the Earth to act like an enormous dynamo, providing our planet with its significant magnetic field.

Virtually solid at its base, the mantle's viscosity steadily decreases until, at around 125 miles beneath the surface, its physical properties change considerably. This marks the lower boundary of the ***'asthenosphere'*** ~ a layer of plasticised rock which extends to within 60 miles of the surface. Above the asthenosphere lies the uppermost part of the mantle ~ a largely solidified region which underpins the planet's brittle crust. It is this fractured outer skin *(or **'lithosphere'**)* which takes the form of various tectonic plates that 'float' on the comparatively fluid rock below. The driving force behind continental drift is thermal energy released by the continuous process of radioactive decay deep within the mantle. Energy from the mantle is carried to the lithosphere by huge convection currents which cause these rigid plates to move slowly around the surface. Indeed the Earth's crust is supported by seven major plates, eight minor plates and an undetermined number of smaller micro-plates. The most massive can carry whole continents and oceans, whilst the interaction of these tectonic plates shapes the entire living world.

As for the composition of the crust, two types of silicate rock predominate. ***'Oceanic crust'*** is largely composed of basalt ~ the most common variety of volcanic rock, whilst the most prevalent constituent of ***'continental crust'*** is granite. A particularly strong crystalline rock, granite is less dense than basalt, allowing the continental crust to ride upon its oceanic counterpart. The land masses themselves are supported by huge continental shelves that rise from the ocean floor and serve to increase the rigidity of the tectonic plates that they sit on. When a plate containing continental crust collides with one that is largely oceanic, the boundary of the latter will invariably be forced down towards the mantle beneath. However the ocean floor is continuously replaced by diverging plates which allow new crystal material to form *(most commonly at mid-ocean ridges)*. The continual growth and subduction of oceanic crust forces the older continental land masses to migrate around the planet; currently at an average rate of 85mm *(just over three inches)* per year globally. Over the past few billion years this process of oceanic floor recycling has led to the formation *(and subsequent break up)* of several super-continents including ***'Pangaea'***, ***'Gondwanaland'*** and ***'Rodinia'***.

The most apparent consequences of tectonic activity are earthquakes ~ abrupt seismic events that can literally rip the ground apart. Most tectonic earthquakes occur on or around fault lines that lie in the vicinity of plate margins. At great depths, the boundaries between plates are less defined as molten rock lubricates their movement. However nearer the surface, rock becomes cooler and less viscous, causing far greater frictional resistance between the co-moving plates. Where the rock is more brittle, facing boundaries can remain locked for millennia before the inertia of the huge plates force them to crack and give way.

A particularly active earthquake zone is that surrounding the Pacific Plate, which is slowly being engulfed by several other plates strengthened with continental crust. As a result the Pacific Ocean is gradually being diminished by the overriding continental plates that surround it, tracing out an enormous 24,000 mile-long horseshoe-shaped belt of tectonic subduction that produces about 75% of the Earth's seismic energy. Known as the ***'Pacific Ring of Fire'***, this is a region of regular earthquakes, active volcanoes and deep ocean trenches. Meanwhile the divergence of plates under the Atlantic Ocean, for example, causes this massive body of water to grow in size. It is dissected by the mid-ocean ridge system, a continuous mountain chain that snakes around the globe for some 40,000 miles. At the ***'Mid-Atlantic Ridge'*** seismic activity results from upwelling magma which forms new oceanic crust, slowly forcing the New and Old World continents apart.

Another major earthquake zone stretches some 5,800 miles from the Mediterranean Sea to the Bay of Bengal. and is caused by the massive Eurasian Plate converging with several others. Particularly powerful *'strike-slip'* earthquakes are common at its boundary with the Arabian Plate, whilst collision with the Indo-Australian Plate has given rise to a number of young mountain ranges including the Himalayas. Of the earthquakes that do not originate close to fault planes, the most destructive are mid-plate quakes which result when internal stress fields attempt to pull apart established continental crust. A prime example of this is the ***'Great Rift Valley';*** a 3,700 mile-long series of continental scars which reveal where the eastern segment of the African Plate is being torn apart by enormous subterranean forces.

The epicentres of earthquakes are often *(but not always)* directly above their focal points *(or hypocentres)*. These hypocentres can lie as much as 400 miles beneath the surface, although the most catastrophic events arise from 'shallow focus' earthquakes that originate from within 40 miles underground. Besides propagating new fractures and liberating heat energy, the release of elastic strain within crystal rock causes it to rupture and rebound. At ground level, this energy is felt as sudden vibrations *(or seismic shock waves)* that radiate outwards at high velocities. Whilst surface waves may only account for a small proportion of the total energy released by an earthquake, it is by far the most destructive element. Indeed numerous heavily populated regions of the world within fault planes are exposed to the ever-present threat of a major earthquake.

Intense shock waves generated at the hypocentres of large earthquakes can have catastrophic consequences when they reach the surface, although a vast majority of energy is dissipated within the planet's interior. Moreover the full force of deep-seated earthquakes is greatly masked by a narrow ½ mile thick region that undulates at an average depth of 22 miles beneath the surface, mirroring the thickness of the crust. Known as the ***'Mohorovičić discontinuity'***, this region causes seismic waves to undergo an abrupt change in velocity as they pass from the uppermost part of the mantle to the crystal rock above. Marking a transition in the density and chemical composition of rock, the 'Moho' discontinuity also has a significant effect on shallow focus earthquakes, reflecting, refracting or even amplifying different types of shock waves as they pass through the Earth's crust.

The apparent intensity of earthquakes is often measured on the ***'Mercalli intensity scale'***, though more specific is the ***'Richter magnitude scale'*** ~ a logarithmic scale which can be used to quantify the seismic energy of an earthquake at its focus. Using this scale, modern seismographs can measure the 'shaking amplitude' of earthquakes with great accuracy ~ each number up the scale representing a tenfold increase in the wave size produced. Because the shaking amplitude of an earthquake is directly proportional to its seismic potential, the amount of energy released when an earthquake strikes can be readily established. As such, a magnitude 7 quake, for example, would be 30 times more powerful than one of magnitude 6, and 900 times more so than a magnitude 5 event. However the Richter scale has its limitations, and been largely superseded by the ***'moment magnitude scale'***; an adaptation which can more accurately distinguish the comparative magnitudes of larger earthquakes.

Every year over 3½ million imperceptible tremors below magnitude 4 are detected around the globe but, on average, only one major earthquake of magnitude 8 or above will occur annually. So far modern civilisation has never endured an epic earthquake of magnitude 10 or higher and, although the Richter and moment scales are open-ended, it is physically improbable that anything over the severity of magnitude 13 has ever occurred as a result of tectonic activity. *(By comparison, the Chicxulub impact* *event 65 million years ago would have generated seismic waves of up to magnitude 16).*

Major earthquakes can, of course, present many serious hazards, most obviously through the violent shaking *(and even rupturing)* of the ground. In a large town or city situated near the epicentre of a major earthquake this can lead to significant loss of life, with the most direct threat coming from the collapse of buildings and bridges. Road and rail are equally susceptible, as are energy grids and pipelines carrying essential gas and water supplies. Other potential dangers can arise from the weakening of reinforced structures such as dams, oil refineries, nuclear power stations and missile silos. Indeed seismic waves have the capacity to destroy the infrastructures of entire cities in a matter of seconds.

When an earthquake strikes, faster moving 'compressional' *(or primary)* waves are the first to break the surface ~ violently shaking the ground back and forth. These are always followed by slower moving 'transverse' *(or secondary waves)* which effectuate a less intense up and down movement on surface objects. This creates a dangerous combination of 'surface waves' whose direction is determined by the physical geography of the region. The combined destructive power of seismic waves is immense, and can create a myriad of different hazards including soil liquefaction, sudden subsidence, scorching of the ground, the release of noxious gasses, and even magma itself *(should a large enough fissure be forced open)*.

The ignition and rapid advance of large firestorms has proven to be a particularly dangerous consequence of earthquakes in urban areas, whilst in mountainous regions earthquakes are widely associated with concomitant disasters such as deadly landslides, and avalanches. Furthermore, active earthquake zones stretch across the whole planet, cutting through manmade boundaries without discrimination. Indeed many major cities in the developed world face the constant threat of being hit and, in financial terms, the damage wrought by a destructive earthquake can run into hundreds of billions of dollars. Far more damaging to humanity however is the cost in human life itself, which is much greater when earthquakes strike poorer regions of the world. Here disruption to vital supplies of fresh water, food and energy can have devastating longer term consequences such as mass starvation and disease, often resulting in huge final death tolls.

The dangers posed to human populations by tectonic earthquakes are not necessarily direct either. For example, they can precipitate serious volcanic eruptions elsewhere along an active plate margin ~ often hundreds or even thousands of miles from the quake's epicentre. When seismic energy is transferred to water it can result in another devastating force that is equally far-reaching. Created when oceanic plates reverberate with seismic ripples, 'tsunamis' are a by-product of many major earthquakes, and can have a serious impact on exposed coastal populations thousands of miles away. Indeed tsunamis can be the most destructive element of an earthquake, crossing entire oceans to wreak havoc on settlements otherwise oblivious to the originating quake. Travelling at speeds of up to 500mph, tsunamis are almost unnoticeable in open ocean, with waves often under 3ft. high. However as they approach shallower seas, the phenomenal energy within the tsunami is 'compressed' by the rising bedrock, causing them to both slow down and gain height. Needless to say coastal inlets are at greatest risk, with waves here capable of reaching heights in excess of 100ft.

Whilst earthquakes have been systematically recorded for well over a thousand years, they were not accurately measured until the start of the 20th century. Subsequently, historic records have been used to determine the approximate magnitudes of infamous earthquakes of the past. Yet the two most powerful earthquakes of the century, were also believed to have been larger than anything previously recorded. The second of these occurred in 1964 when a huge earthquake of magnitude 9.2 struck 75 miles south-west of Anchorage in Alaska. Although it caused serious damage to several towns in Prince William Sound, thanks to its remoteness ***'The Great Alaska Earthquake'*** resulted in comparatively few casualties ~ killing 131 people *(mostly from the resulting tsunamis)*. However the surface energy distributed by this quake was truly great. With aftershocks continuing for well over a year, its seismic yield was equivalent to the detonation of 32 gigatons of **TNT** *(making it about 630 times greater than the largest thermonuclear weapon ever tested)*.

As big as it was, the Alaskan event was dwarfed by ***'The Great Chilean Earthquake'*** of 1960 which had a series of epicentres ~ the largest near the small town of Cañete, some 440 miles south of Santiago. Destroying vast swathes of land along the Pacific coastline of southern Chile, this earthquake measured 9.5 on the moment magnitude scale, and was nearly six times larger than the one that would strike Alaska four years later. Besides causing considerable damage to various populated areas *(particularly the coastal city of Valdivia)*, the earthquake had a major impact on the regional geography, setting off landslides that choked local rivers, changed their courses and created new wetland areas. The greatest extent of its force in terms of cost to human life however, was felt as a series of tsunamis that swept across the Pacific Ocean, laying waste to exposed communities in Hawaii, Japan and the Philippines a few hours later. In all, up to 6,000 lives were lost as a result of this widespread disaster.

The Great Chilean Earthquake was a truly massive event but, like all earthquakes, its seismic potential *(i.e. the energy that actually percolates the surface)* accounted for less than 3% of the total energy released at its focus. It is just as well that the surface was only subjected to such a tiny proportion of its force, when you consider that this earthquake ultimately generated 250 million, billion joules of energy. This is the equivalent to detonating 60 teratons of **TNT** *(or about 3½ billion times more energy than was liberated by the Hiroshima bomb)*. So immense was the Great Chilean Earthquake that its energy reverberated throughout the entire mass of the planet, allowing seismic waves to be detected around the globe for several days. It even sent the planet into a state of *'seismic free oscillation'* ~ a phenomenon that caused 'palpitations' in the natural wobble *(or 'variation of latitude')* of the Earth's rotation.

Although the Chilean and Alaskan earthquakes of the 1960's were two of the largest to have ever been recorded, they were by no means the most deadly. The impact of an earthquake on the human population is as much down to its location, intensity and timing as it is its size. Indeed few of the most catastrophic earthquakes in human history would have registered more than magnitude 8 using modern seismographs, yet their impact on early civilisation would have been profound.

Of the numerous major earthquakes have taken their place in history over the last millennia, one of the most deadly struck northern Syria in 1138. Killing around 230,000 people and further devastating a region that had already been ravaged by war, the ***'1138 Aleppo earthquake'*** was the largest in a number of lethal quakes to have shaken Asia Minor in the mid-12th century. Coming, as it did, in the aftermath of the First Crusade, the destruction wrought by this earthquake also served to increase tensions and help change the balance of power in the region, effectively perpetuating this series of implacable religious wars.

An earthquake with even greater historical significance however was the ***'Great Lisbon Earthquake'*** of 1755, whose resulting firestorms and tsunamis took the lives of nearly 100,000 people across parts of Western Europe and Northern Africa. Yet, as destructive as it was, this earthquake had a sublime effect on the intellectual *'enlightenment'* of European culture, instigating a great deal of philosophical thought about its human consequences. Indeed the earthquake captured the minds of some of Europe's greatest thinkers including **'Voltaire'**, **'Jean-Jacques Rousseau'**, and **'Immanuel Kant'** whose ideas challenged established theological beliefs regarding its cause. In a growing atmosphere of reason, the idea proffered by the church that earthquakes were a form of 'divine punishment for immoral behaviour' seemed increasingly absurd, and the Lisbon quake marked the embryonic beginnings of seismology as a legitimate field of scientific study.

The concept of natural balance is deeply ingrained in Eastern philosophy, and earthquake awareness has become very much a part of the public psyche in places such as China and Japan. Central East Asia is not only a hotbed of tectonic activity, but is the most heavily populated region of the world, and it is not uncommon for larger earthquakes to claim the lives of over 100,000 people. Indeed the deadliest recorded earthquake in human history was the ***'1556 Shaanxi earthquake'*** which caused extensive damage to a large area of central China, and claimed an estimated 830,000 lives. Centred near Mount Hua in Shaanxi, the earthquake brought widespread destruction to a number of neighbouring provinces, killing over half the population in several rural counties.

China also suffered the worst earthquake disaster in modern history when the ***'Great Tangshan Earthquake'*** of 1976 struck near a large industrial city in a region not previously considered to be at high risk. Killing around 650,000 people *(although the official death toll is nearer 240,000),* the Tangshan quake came at a time of extreme social upheaval. With millions of people still suffering from China's failed *'Cultural Revolution'*, the disaster exacerbated the misery of the regional population. This in turn had enormous political repercussions for the country's ruling elite, and ultimately catalysed the reforms that would turn China into an economic superpower.

20th century China has been subjected to numerous violent earthquakes which have caused devastation on a truly massive scale. The ***'1920 Gansu earthquake'*** was one of the most intense, and could be felt throughout most of the country ~ with aftershocks periodically shaking the region for a further three years. The epicentre of the Gansu quake was in Haiyuan county *(in modern day Ningxia)*, and it caused severe damage in several provinces of central China, with landslides and extensive flooding raising the final death toll to well over 200,000. In the 1920's alone earthquakes killed many thousands of people across China with large numbers of casualties in Sichuan *(1923)*, Yannan *(1925)* and Xining *(in 1927)*.

However the decade was not just a particularly tragic one for quakes in China, the wider region also suffered greatly. The ***'Great Kantô Earthquake'*** of 1923, for example, claimed around 140,000 lives, mostly from across the Honshû mainland of Japan. Centred beneath a small island in the mouth of Sagami Bay, the Kantô earthquake wrought destruction throughout Japan's most heavily populated region, levelling large parts of Tokyo and Yokohama. Tsunamis with waves of up to 30ft. laid waste to many coastal settlements between the Izu and Bōsō peninsulas, whilst huge landslides killed many hundreds of people in inland towns and villages. By far the biggest killer in the cities however was fire, with the largest firestorms raging out of control for several days. This in turn brought widespread panic and disorder as hundreds more people perished in the 'mob rule' that ensued, with anarchy and paranoia resulting in the persecution of Korean minorities.

Extensive fires and civil unrest also marked one the most infamous quakes of the century, which had struck on the other side of the Pacific rim two decades earlier. Centred two miles offshore, near Mussel Rock in California, the ***'1906 San Francisco earthquake'*** ruptured a 300 mile stretch of the ***'San Andreas Fault'*** causing considerable damage to numerous cities around the San Francisco Bay area ~ including San Jose, Oakland and Santa Rosa *(whose central district was virtually destroyed)*. It resulted in the deaths of over 3000 people, many from the manmade firestorms that followed the initial quake. Indeed the major cause of death in this catastrophe was fire, with those caused by exploding gas pipes and broken electricity cables being exacerbated by badly misjudged firebreaks and severely damaged water mains. San Francisco itself suffered from arson on a huge scale, largely brought about by the fact that nearly all insurance policies covered properties destroyed by fire but not earthquake damage.

Whilst, in terms of lives lost, the 1906 San Francisco earthquake represents the worst natural disaster in California's history, seismic activity elsewhere along the American margin of the Pacific Ring of Fire has brought far greater loss of life. Regions of Argentina, Peru, Nicaragua and Guatemala have all suffered enormously from major earthquakes in the 20th century. Equally devastating earthquakes have also struck heavily populated countries within the active zone that marks the long southern boundary of the great Eurasian Plate. During the last century, populations in Italy, Turkmenistan, Armenia, Iran and Turkey have all been blighted by major earthquakes ~ each resulting in many tens, or even hundreds, of thousands of casualties.

Some of the deadliest earthquakes in the first years of the 21st century have also occurred along the Eurasian Plate boundary. Convergence with the Indo-Australian Plate has resulted in a huge seismic zone stretching from Iran in the west to Indonesia in the east. The India/Pakistan border, for example, is a particularly active region with the ***'2001 Gujarat'*** and ***'2005 Kashmir'*** earthquakes killing over 100,000 people between them. The most destructive natural disaster of the early 21st century however was the ***'Great Sumatra-Andaman Earthquake'*** of 2004, whose tsunamis destroyed thousands of miles of Indian Ocean coastline. Measuring 9.3 in magnitude, the Sumatra-Andaman event was the second largest earthquake in modern history, and the succession of tsunamis it generated devastated coastal populations across Indonesia, Sri Lanka, India and Thailand *(as well as causing considerable damage to parts of the east African coast)* in all claiming over 230,000 lives. With the original epicentre of this great earthquake lying some 60 miles off the west coast of northern Sumatra. the nearby district of Aceh *(an autonomous region of Indonesia)* naturally felt the full force of the first tsunamis, with the largest recorded waves here as high as 100ft. ~ some of which washed well over a mile inland.

Centred less than twenty miles beneath the Indian Ocean, this was a particularly destructive shallow focus earthquake that lasted for nearly ten minutes. Initial seismic activity off the northern Sumatran coast began a chain reaction that ruptured nearly a thousand miles of undersea fault line, causing it to travel northwards at high speed past the Andaman and Nicobar Islands, setting off further tsunamis on the way. So powerful was the Sumatra-Andaman event that massive aftershocks continued for several months, the largest of which *(between magnitudes 6.6 and 8.7)* could be considered major earthquakes in their own right. Indeed shock waves from the main quake reverberated around the planet for many days, and it triggered a number of volcanic eruptions across parts of northern Sumatra. As a result of the earthquake, the northernmost section of the Indo-Australian Plate slipped some 50ft. under the Burmese micro-plate *(a fused section of the great Eurasian Plate)*. This caused the seabed to lift slightly, thus reducing the capacity of the Indian Ocean and causing a small but 'permanent' rise in global sea levels. Even more spectacularly, like most other great *'megathrust'* earthquakes of magnitude 9 and above, the Sumatra-Andaman quake had an *(albeit diminutive)* effect on the Earth's rotation, reducing the length of a day by about 2.6 nanoseconds.

The most harmful consequences of the Great Sumatra-Andaman Earthquake however were far more apparent, with its tsunamis causing incalculable long-term environmental damage. Not only did the resulting sea surges further destroy already depleted areas of coral reef, mangrove swamp, coastal forest and wetland, but they contaminated vast swathes of agricultural land in one of the poorest regions of the world. With productive soil and freshwater supplies infiltrated by saltwater, industrial chemicals and raw sewerage, the potential for widespread starvation and disease was considerable. Thankfully humanitarian aid provided by the international community *(largely through privately-funded efforts)* prevented an even greater disaster.

vi.

*(**Terrestrial calamities:** Volcanoes and supervolcanoes)*

With the human population in excess of 8 billion and rising, it has been estimated that a major earthquake at the wrong place and time has the potential to kill up to 3 million people at a stroke. Indeed earthquakes are the most deadly of the tectonic forces that human civilisation has so far had to endure. Volcanic eruptions by comparison, though more spectacular, have historically caused far fewer casualties. However modern man has yet to witness a truly massive eruption.

Volcanoes are most commonly perceived as being conical-shaped mountains with summit craters that periodically spew lava and eject large plumes of hot gas, ash and rock. Yet these 'classic' ***'stratovolcanoes'*** account for a very small percentage of the Earth's volcanic activity, which can take various other forms including ***'cinder cones'***, ***'shield volcanoes'*** and ***'seamounts'***. Indeed a vast majority of the planet's lava output occurs through ***'fissure volcanism'***, where magma is 'gently' extruded at the oceanic ridges, and therefore goes largely unnoticed.

At temperatures ranging anywhere between 650-1200º**C**, lava flows are themselves equally varied. Silicate-rich *'felsic'* magma, for example, produces highly viscous lava that can create slow-moving 'block flows'. Hotter *'mafic'* lavas, on the other hand, result from the extrusion of iron-rich basaltic magma and tend to be much more fluid. This makes mafic lavas somewhat more hazardous, allowing them to spread a lot further from the main vent, with some flows reaching speeds in excess of 60mph.

The explosive element of a volcanic eruption however is far more dangerous. Known as pyroclasts *(or tephra)*, the ejecta from an erupting volcano contains highly volatile materials, ranging from dust-sized particles to enormous blocks *(or 'bombs')* weighing many tons. At over 20 miles high, some eruption columns can reach well into the upper-stratosphere and deposit ash at distances in excess of a thousand miles from the volcano itself.

When the exterior of an eruption column collapses under the weight of tephra, pyroclastic flows are produced. Seen to billow from the sides of many explosive volcanoes, these enormous clouds of hot gas and rock can reach temperatures of over 1000º**C** and travel at high speeds for many miles ~ incinerating everything in their paths. Hugging the ground as they balloon outwards, pyroclastic flows deposit millions of tons of hot rock and dust over large areas. At the base of a flow, the heaviest boulders and rock fragments smash through trees and buildings, whilst the lighter materials at the top, heat the turbulent air around it, causing the flow to expand and dilute, as it spews from the erupting volcano.

Many large flows are preceded by pyroclastic surges. These occur when the convection currents within the surrounding air can no longer support the concentrated mixtures of steam and other hot gasses ejected during an eruption. Containing predominantly lighter materials, such as dust, ash and various poisonous compounds, pyroclastic surges can move at speeds of over 250mph. and travel far from the erupting vent. Indeed the energy within a surge can even force these lethal currents up inclines, overwhelming vast tracts of land that would otherwise escape the main thrust of a pyroclastic flow.

Hugely destructive on land, pyroclastic flows and surges are equally devastating when they encounter seas and lakes. Larger, heavier materials explode on contact with water and can produce significant tsunamis, whilst the gasses and lighter particles can cross large stretches of water on cushions of superheated steam, travelling many miles before eventually cooling and dissipating. Equally dangerous are lahars, fast moving mud flows that can occur whenever an eruption disturbs a lake, glacier or permanent snow cover. Most often consisting of melt water choked with volcanic debris, lahars can reach speeds of over 80mph. in full flow, yet can set like concrete once they have stopped. The largest can deposit many millions of tons of material, sometimes covering land in volcanic mud hundreds of feet deep.

Whilst the most dramatic displays of environmental destruction naturally occur around an exploding vent during the eruption itself, volcanic activity can also have catastrophic long-term consequences across huge areas. The largest eruptions can even have a considerable effect on the global climate by subtly altering the composition of the atmosphere. Indeed volcanic activity around the planet releases hundreds of millions of tons of carbon dioxide and numerous noxious gasses into the atmosphere every year.

The most sublime atmospheric changes brought about by volcanic eruptions result from the production of fine sulphate aerosols. These form at high altitudes from the conversion of sulphur dioxide *(an abundant volcanic gas)* to sulphuric acid, and can seriously damage the biosphere in a number of ways. By reflecting sunlight, the presence of sulphate aerosols increases the planet's albedo, and can cause global temperatures to fall. Forming at such high altitudes, sulphate aerosols are not readily dispersed by the planet's weather systems. Rather, they coagulate before eventually collecting in the upper-troposphere where they can readily seed cirrus clouds, further altering global weather patterns.

Although they may help to cool the surface of the Earth, sulphate aerosols conversely absorb heat radiated from the planet below, thus raising the temperature of the surrounding stratosphere. Moreover, the composition of the stratosphere is itself subtly altered by the injection of both volcanic gasses and human pollution. A particularly damaging by-product is chlorine monoxide ~ a pungent gas which breaks down the natural layer of ozone that protects the biosphere from harmful ultraviolet solar radiation. The most abundant element produced by volcanic activity however is hydrogen, much of which is expelled as steam. Other hydrogenous volcanic gasses, such as hydrogen chloride and hydrogen fluoride, are far more conspicuous. These compounds readily dissolve in water droplets which invariably fall as acid rain in the vicinity of an erupting volcano. This, along with reduced sunlight, can cause widespread crop failure leading to serious famine in the poorest volcanically-active regions of the world.

Another type of natural phenomenon associated with active volcanoes are volcanic earthquakes which can be just as catastrophic as their larger tectonic equivalents. Volcanic earthquakes result from the movement of magma beneath the surface. As pressure builds within the magma chamber of an active volcano system prior to an explosive eruption, it can cause abrupt changes in stress within the surrounding bedrock. Indeed seismologists have successfully used 'volcanic tremor signal' patterns to predict impending eruptions. Yet volcanic earthquakes can prove enormously destructive ~ one of the deadliest striking Sicily and Malta in 1693 as a portent of ***'Mount Etna'***s impending eruption. Although the earthquake killed over 60,000 people and destroyed many towns and cities throughout the central Mediterranean region, on this occasion the eruption of Etna itself claimed few lives.

A particularly explosive volcano *(and the largest in Europe)*, Mount Etna is also one of the most active volcanoes in the world. It is peppered with eruption vents along its flanks, and its large, restless summit craters have produced numerous recorded eruptions. Lying at the foot of the volcano, Sicily's second city Catania, has been engulfed by lava on several occasions throughout its long history, and was razed by the devastating 1693 earthquake. Indeed Catania was still recovering from a particularly destructive eruption whose lava flows had torn through the city 24 years earlier, killing some 20,000 people.

Another volcano to have left its mark in human history is ***'Mount Vesuvius'***, which lies on Italy's west coast, some 220 miles north of Etna. Nestled in the bay of Naples, Vesuvius has had countless violent eruptions over the past 20,000 years and is considered to be one of the most dangerous volcanoes in the world. Its most infamous eruption of 79**CE** demolished several Roman settlements including the cities of Pompeii and Herculaneum, killing around 3,000 people. About the same number had lost their lives in a powerful earthquake seventeen years earlier ~ the largest of many to precede the 79**CE** eruption. However this was by no means the first time that Vesuvius had ravaged the local population, with evidence that many Bronze and Iron Age settlements, lured by its fertile volcanic soil, had been overwhelmed by pyroclastic surges and ash fall. Subsequent Vesuvian eruptions, though less intense, have destroyed numerous towns and villages in the region over the past millennium. In 1631 a particularly violent eruption marked a deadly new phase of severe, regular eruptions that would continue for over three centuries and kill several thousand people. Although Vesuvius has remained dormant since 1944, today over 3 million people live in close proximity to the volcano, and should another major eruption occur, it could be the most deadly in human history.

An especially notable volcano of great historical significance is that of ancient ***'Thera'*** *(now more commonly known as Santorini)* ~ a volcanic island in the Aegean Sea. In the 16th century **BCE** a massive eruption obliterated the island, and devastated much of the ancient world. It contributed to the decline of Minoan culture which represented Europe's earliest great civilisation, Centred in Crete, the Minoans were a seafaring people who dominated the region a thousand years before the rise of

Classical Greece. The devastation caused by the event weakened their power base considerably, and within a century Minoan civilisation would be overrun by the Mycenaeans ~ a new dominant force from the mainland. The eruption itself was preceded by a number of powerful earthquakes that caused widespread destruction, and was followed by several tsunamis which engulfed the northern coast of Crete *(a mere 75 miles south of the volcano)*. Much of the eastern Mediterranean suffered from serious ash fall, whilst climatic changes throughout the wider region effected much of Eurasia and North Africa, with subsequent crop failures adding enormous stress on early civilisations in the near East. As well as giving rise to biblical stories of exodus and plague, the Thera eruption inspired several Greek myths including the legend of Atlantis.

The southernmost of the Cyclades, the island of Santorini and its accompanying islets 'arc' around a submerged caldera *(a subsided crater-like formation)* formed by this colossal explosion some three-and-a-half thousand years ago. Santorini itself has undergone great change as volcanic activity continuously rebuilds and collapses the island from within, in an ongoing cycle that has lasted hundreds of thousands of years. Sporadic eruptions occur on the Kameni islands that emerged from the centre of the caldera in 1570, and continue to grow *(the last recorded activity occurring in 1950)*.

Other volcanoes, although just as active, appear timeless in their presence and domination of the landscape. For over 700,000 years the iconic ***'Mount Fuji'***, for example, has grown in volume considerably, having undergone a process of continuous building without major collapse. 'New Fuji' *(as it is often referred)* overlays older volcanoes and is Japan's highest peak, rising majestically from the shores of Suruga Bay some 60 miles south-west of Tokyo. Revered in Japanese art and literature, Fuji has erupted sporadically throughout the ages with numerous historical accounts of violent activity. The mountain's last eruption in 1707-8 was preceded by a powerful earthquake, whilst fallout from the explosion itself buried several nearby towns under a thick blanket of hot cinders and black ash. As spectacular as it is, Fuji however is by no means the largest volcano in the world. The highest volcanic peaks are to be found throughout the Andean regions of Chile, Argentina and Ecuador. These include ***'Cotopaxi'***, ***'San Pedro'*** and the mighty ***'Ojos del Salado'*** which peaks at over 22,600 feet *(4.2 miles)* above sea level. The largest volcano by volume however is ***'Mauna Loa'*** in Hawaii ~ a massive shield volcano whose bulk exceeds 18,000 cubic miles, and extends some 6.3 miles from the Pacific ocean floor.

Yet the physical size of a volcano has little to do with its explosive potential. As large as it is, Mauna Loa, for example, is characterised by frequent eruptions that emit large quantities of lava, but are rarely explosive. More critical is the force with which magma is extruded, and the *'volcanic explosivity index' (or **VEI**)* is the most commonly used method of measuring the relative explosiveness of different volcanic eruptions. Based on various factors including the volume of ejecta and the height of eruption cloud, the volcanic explosivity index is an open-ended scale where each increment represents a tenfold increase in explosiveness. Although it does not account for the duration and temperature of an eruption *(and therefore its total energy output)*, the **VEI** scale has proven very useful in comparing the sizes of unobserved prehistoric eruptions with those of historic significance.

Using **VEI**, the explosivity values of all known eruptions have been determined and rated from non-explosive *(**VEI**-0)* to mega-colossal *(**VEI**-8 and above)*. Comparative data has revealed that the 1815 eruption of ***'Mount Tambora'*** *(at **VEI**-7)* was the largest for over 1600 years. Located on the Indonesian island of Sumbawa, the volcano exploded with extraordinary violence, erupting up to 39 cubic miles *(160km³)* of tephra from a column that skirted the upper stratosphere. By comparison the paroxysmal **AD**79 eruption of Vesuvius *(measuring **VEI**-5)* ejected around one cubic mile of ash and rock, whilst the colossal Minoan eruption of Thera *(**VEI**-6)* expelled some 14 cubic miles of material.

Classified as a super-colossal event, the Tambora eruption devastated many islands in the Malay Archipelago and became the deadliest in recorded history, causing *(directly or otherwise)* the deaths of up to 90,000 people. Lasting for six days, it destroyed virtually all the vegetation on Sumbawa and the neighbouring island of Lombok. This massive eruption generated vast pyroclastic currents that obliterated everything in their paths, and a plume that created total darkness in the region for several days ~ depositing a blanket of ash that stretched for over 800 miles. It sent a moderate-sized tsunami reverberating around the archipelago, whilst the cohesion of uprooted trees and volcanic debris formed huge pumice rafts, several miles across, that littered the Java Sea. Its effect on the wider world was also profound. Causing a high concentration of sulphur in the stratosphere, the eruption created a veil of sulphate aerosols which reduced global temperatures by over 0.5°**C**, making 1816 (*'the year without a summer')* the coldest for more than two centuries. Subsequent famine and disease claimed innumerable lives.

Another infamous eruption of the 19th century occurred in 1883 on the Indonesian island of ***'Krakatau'***, in the Sunda Strait between Sumatra and Java. Although about a seventh the size of Tambora, at **VEI**-6 the colossal eruption of Krakatau ejected around 6 cubic miles *(25km³)* of material, with associated pyroclastic flows, earthquakes and tsunamis claiming the lives of some 36,500 people. The eruption was preceded by months of intense seismic activity which *(besides causing considerable damage on land)* opened up fissures that allowed seawater to seep into the network of volcanic vents beneath the island. This served to increase the volatility of the magma chamber, raising its pressure considerably. The extraordinary amount of energy released as magma 'prematurely' burst through the rock, resulted in the loudest sound ever recorded ~ creating a pressure wave that encircled the Earth. Culminating in four massive explosions *(each producing a devastating tsunami)* the eruption could be distinctly heard over 3,000 miles away. Like Tambora, Krakatau had a profound effect on global weather patterns and, like Santorini, the island continually undergoes the process of sudden destruction and slow rebuilding, with the new island of Anak Krakatau first emerging in 1928.

The 20th century also saw its fair share of catastrophic eruptions. One of the first was the cataclysmic explosion of ***'Mount Pelée'*** in 1902 which killed over 30,000 people on the Caribbean island of Martinique. Rated at **VEI**-4, the most deadly element of

Mount Pelée's eruption were its pyroclastic flows which obliterated the town of Saint-Pierre and devastated several others that lay to the east of the volcano. At **VEI**-5, the eruption of ***'Mount St. Helens'*** in 1980 became the largest on the North American continent in modern history. Located in Washington, **USA**, Mount St. Helens is one of the most heavily studied volcanoes in the world and its paroxysmal eruption of 1980 advanced volcanology tremendously. Indeed it is often used a 'yardstick' to construe the sizes of other notable eruptions. Although it killed a comparatively small number of people *(official death toll 57)* the eruption of Mount St. Helens caused incalculable damage to the carefully managed environment around it, costing the **US** economy over $1 billion.

Less intense, but far more deadly, was the eruption of ***'Nevado del Ruiz'*** in 1985 which caused some 23,000 fatalities. The severe *(**VEI**-3)* eruption of this Colombian volcano set off a huge lahar that completely engulfed the nearby town of Armero in a matter of minutes, killing over two-thirds of its population. In 1991 ***'Mount Pinatubo'***, on the main Philippine island of Luzon, erupted with colossal force making it the last *(and second largest)* major eruption of the century. Preceded by a massive earthquake just a few months earlier, the prolonged eruption of Pinatubo *(rated **VEI**-6)* sterilised a large area of Luzon and covered almost the entire island with ash fall. However despite enormous pyroclastic currents and persistent lahars, accurate prediction of the impending eruption, and well prepared evacuation procedures ensured that the volcano would claim comparatively few *(some 1,200)* victims.

As destructive as they are, the largest volcanic eruptions so far experienced by modern humans pale into insignificance when compared to the enormity of what have become termed ***'supervolcanoes'***. Too large to be supported by the mountainous bulks associated with stratovolcanoes and shield volcanoes, these enormous features can produce calderas which are so immense that they are often difficult to identify. Belying the incredible volcanic activity beneath, supervolcanoes have the potential to produce mega-colossal eruptions that could give rise to the most devastating of apocalyptic scenarios.

Whereas most volcanoes form near the boundaries of continental and oceanic plates *(extruding magma from the underlying asthenosphere)*, supervolcanoes can occur anywhere on the planet, drawing their energy from a far deeper source. Indeed almost all supervolcanoes derive from geological ***'hotspots'*** which are created by columns of exceptionally hot magma that well up from the mantle itself ~ pooling in vast reservoirs of molten rock often just a few miles beneath the surface. These enormous 'mantle plumes', as they are known, behave somewhat like 'lava lamp bubbles' ~ thinning out as they rise whilst becoming increasingly bulbous at the top. Should a plume reach the base of the lithosphere, decompression melting causes it to flatten out and partially infuse with the surrounding rock ~ forming a hotspot on the surface. Depending on the continuity of supply from a stream of rising magma, the resulting hotspot may eventually subside, or periodically burst through the Earth's crust with catastrophic consequences. The mantle plumes themselves can typically last for tens or even hundreds of millions of years *(by comparison most volcanoes remain active for just a few hundred thousand years)*. As a result, over millions of years, hotspots *(which appear 'fixed' to the planet's interior)* trace the movements of overlying tectonic plates, leaving a geological record of continental drift.

Whilst we are presently undergoing a period of relative hotspot inactivity, not all hotspots give rise to supervolcanoes. Indeed a number of 'smaller' hotspots are very much active today. Examples include the ***'Iceland'***, ***'Azores'*** and ***'St. Helena hotspots'*** which run along the Mid-Atlantic ridge where diverging plates have stretched the lithosphere, allowing thin mantle streams to break the surface and form volcanic islands. There are also a number of active 'mid-plate' hotspots which include several pairs of antipodal sites. This has led to the hypothesis that some may have been caused by head-on collisions with large meteoroids ~ with such impacts transferring energy through the entire planet. One example is the ***'Hawaii hotspot'*** in the central Pacific Ocean and the ***'Réunion hotspot'*** which lies in the western Indian Ocean. Despite being on opposite sides of the Earth, these hotspots share many similarities, both having formed island chains of similar age and size from large and highly effusive shield volcanoes. Thankfully, although they experience continual outpourings of lava, compared to many prehistoric eruptions, both hotspot sites currently produce comparatively small amounts of ejecta.

At least five major extinctions in prehistory, however, have coincided with periods of massive sustained volcanism that are associated with intense hotspot activity. These include the Permian-Triassic transition *(approximately 248 million years ago)* which marked the most profound of all prehistoric mass extinction events. The ends of other geological periods, such as the Triassic *(around 206 million years ago)*, the Jurassic *(about 142 million years ago)* and the Cretaceous *(some 65 million years ago)*, were also accompanied by the mega-colossal eruptions of one or more supervolcano. Indeed when large mantle plumes break the surface they can have severe global consequences, and were such an event to occur today it would be by far the biggest natural disaster in human existence.

Broadly speaking, hotspots can produce two distinct types of supervolcano; those that erupt violently with extreme explosive force, and those that produce non-explosive but prolonged outpourings of lava. The latter *(known as **'flood basalt events'**)*, whilst being less intense, are highly effusive eruptions where magma seeps out of the surface, much like 'blood from a graze'. With eruption pulses lasting from a few hundred to a few million years, the largest can produce basaltic magma on a monumental scale, liberating enough lava to reshape entire continents. As a result flood basalt events can have a catastrophic effect on the biosphere, deoxygenating oceans and poisoning the atmosphere with toxic gasses.

Collectively known as *'large igneous provinces'*, the remnants of prehistoric flood basalt events are evident around the world, appearing as a variety of geological formations including dykes, sills and plateaux. Most prominent hotspots tend to appear beneath oceanic crust where the lithosphere is least resistant, resulting in vast outpourings of lava which have periodically brought about the collapse of entire oceanic ecosystems. Indeed large igneous provinces can cover several million square miles and the basaltic outpourings that form them can kill on a global scale. The most massive large igneous provinces include the ***'Central Atlantic Magmatic Province'*** which was laid down approximately 200 million years ago ~ as Pangaea started to break apart in the early Jurassic Period. Today it covers an immense area of nearly 4¼ million square miles, extending across the Atlantic Ocean from North America to West Africa. The largest by volume however is the ***'Ontong Java Plateau'*** located in the equatorial region of the Western Pacific, which initially erupted around 125 million years ago, and extruded some 24 million cubic miles of basaltic magma,

Large igneous provinces however are not confined to the oceans, with a number of flood basalts having engulfed large areas of land. When continental crust is invaded by such events, step-like hills *(or 'traps')* are built as numerous layers of lava are laid down and solidified. One such formation is the ***'Siberian Traps'*** ~ an enormous province whose creation coincided with the end-Permian mass extinction some 250 million years ago. This vast outpouring of lava continued for over a million years and coated some 2½ million square miles of land. It exacerbated the calamitous effects of at least one other supervolcanic eruption in a combined event that annihilated life on a scale that has never been surpassed. Another, the ***'Deccan Traps'*** *(which covers a vast area of central India)*, was laid down some 65 million years ago, possibly as a reaction to the Chicxulub impact. Whilst erosion has reduced this enormous feature to around 20% of its original size, the initial traps extended for well over half-a-million square miles and no doubt contributed to the Cretaceous extinction. Its source was a hotspot that is still active today, and now feeds the ***'Piton de la Fournaise'***; the principal volcano of Réunion island about 500 miles east of Madagascar.

Although no major flood basalt events have occurred for several million years, it has been suggested that the formation of Iceland represents the early stages of just such an event. However, perhaps the closest thing to a flood basalt eruption that is presently observable is the persistent activity of ***'Kïlauea'*** ~ the smaller companion of Mauna Loa on Hawaii. Currently the world's most active volcano, Kïlauea has been spewing lava continuously since 1983, and its present eruption has so far claimed nearly fifty square miles of land.

Whilst most of the Earth's hotspot activity manifests as prolonged non-explosive outpourings of lava, generally speaking when hotspots break through continental crust they give rise to the most violent and explosive of all volcanic eruptions. Because it is thicker and less dense, continental crust tends to slow the progress of rising magma, preventing direct seepage to the surface. This leads to the formation of rhyolitic magma, a far more viscous, silica-rich material. Should the head of a mantle plume remain attached to its source, pressure will continue to rise until magma is forced through the overlying bedrock in an explosive super-eruption. Measuring at least **VEI-**8, super-eruptions are enormous mega-colossal events that eject no less than 240 cubic miles *($1000km^3$)* of material in a matter of days ~ three orders of magnitude greater than the eruption of Mount St. Helens. So intense are these eruptions that ejected material spontaneously disintegrates when it punches through the surface and, when the magma chambers are eventually emptied, the ground above often collapses to form vast calderas that can measure up to a hundred miles across.

Some fifty supervolcanic calderas are known around the world, ranging from less than 100,000 to several hundred million years old ~ a vast majority of which are now extinct. ***'La Garita'*** caldera, located in south-western Colorado, marks the epicentre of the largest supervolcanic explosion so far identified. Exploding about 27.8 million years ago, the La Garita eruption would have rated a staggering **VEI-9**, and is believed to have blanketed most of the North American continent with ash fall. The remaining deposits from this almighty eruption *(known as the **'Fish Canyon Tuff'**),* although greatly reduced by erosion, still exceed a volume of 1,200 cubic miles.

Although smaller than La Garita, supervolcanic eruptions have also occurred since the existence of mankind. Approximately 74,000 years ago a supervolcano, located beneath what is now ***'Lake Toba'*** on the Indonesian island of Sumatra, had a devastating effect on humanity. The huge caldera seen today covers an area some 60 miles long by 20 miles wide, and the Toba eruption *(which ejected around 670 cubic miles of material)* covered the entire Indian subcontinent and much of Southeast Asia with ashfall. In terms of the volume of material ejected, this eruption was roughly a thousand times larger than Mount St. Helens *(by comparison the greatest historic eruption, that of Mount Tambora in 1815, was only some sixty times greater).* Evidence of the abrupt change brought about by this unimaginably huge eruption has been found in Arctic ice cores, and it is now believed to have expelled over two billion tonnes of aerosols into the atmosphere. This would have almost completely blocked out the Sun for several months, and further effected the global climate for many decades after. Global temperatures would have dropped by an average of some 3.5º**C**, at a time when early humans were already facing the harsh challenges of an oncoming Ice Age. Indeed the eruption was so profound that it caused temperatures in northern latitudes to fall by up to 5º**C**, freezing European summers and plunging much of the planet into a long volcanic winter.

The effects of the Toba eruption would have been catastrophic for life, and is known to have created a 'bottleneck' in genetic diversity across the globe. Indeed the eruption would have annihilated vegetation throughout Southeast Asia *(and much the wider world)* leading to the collapse of entire ecosystems. As a result early man was devastated, with human numbers plummeting from approximately sixty million to just few thousand worldwide. Whilst isolated populations of Archaic *Homo sapiens* and other hominid species were sent into rapid decline *(and eventual extinction)*, evidence in our own mitochondrial **DNA** suggests that all modern humans are descended from a relatively small number of survivors.

Lying close to the 'Sumatra fracture zone', at least two other caldera-forming eruptions have occurred at Lake Toba in the past million years. Moreover, activity continues to this day beneath the lake *(and Samosir Island at its centre)* with the occasional earthquake a reminder of the restless magma chamber that feeds it. Yet surprisingly Lake Toba is not the site of the last supervolcanic eruption to have occurred. That happened beneath what is now ***'Lake Taupo'***, near the geographical centre of New Zealand's North Island around 26,500 years ago.

The ***'Oruanui eruption'***, as it is known, ejected some 280 cubic miles of material in just a few days. However it exploded, long before human settlement in the region, and its remoteness *(in the Southern Pacific, well over a thousand miles from the nearest continent)* meant that it caused comparatively few fatalities. Lake Taupo's most recent major eruption in 181**AD** left somewhat more of an impression on mankind. Though much smaller, the ***'Hatepe eruption'*** exploded with extraordinary ferocity ~ ejecting some 30 cubic miles of tephra in under an hour. At **VEI-**7, it was comparable in size to Tambora, and did not go unnoticed by early civilisation, with red skies being recorded as far away as Southern Europe and Eastern Asia.

Current activity beneath lakes Toba and Taupo suggests that the threat of a major eruption at either site in the foreseeable future is negligible. However the largest active supervolcanic system so far discovered is also the most menacing, and has the potential to push humanity to the brink of extinction. Considered a 'high threat' system, the ***'Yellowstone hotspot'*** overlies a huge magma chamber which has periodically erupted for at least 17 million years.

The hotspot currently lies beneath what is now Yellowstone National Park in north-west Wyoming yet, in geological terms, its arrival there has been comparatively recent. As the North American Plate has slowly moved over the hotspot, it appears to have migrated north-eastwards scarring the continental crust above. Forming a 70 mile wide channel through the Rocky Mountains, the hotspot's passage has laid down the entire eastern section of the Snake River Plain ~ a massive depression that cuts through the state of Idaho. Its 450 mile-long prehistoric trail of destruction is evident in the geological features of the region, with numerous eruptions over the last 15 million years having been identified along its path. These include huge calderas and tuff formations as well as extensive lava fields and plateaux, suggesting that the hotspot has given rise to both colossal rhyolitic eruptions and prolonged outpourings of basaltic magma. Approximately ten million years ago, for example, the hotspot caused a massive eruption in southern Idaho, known as the ***'Bruneau-Jarbidge eruption'***, for which there is strong palaeontological evidence of a major extinction event.

Initially erupting at Yellowstone National Park 2.1 million years ago, hotspot activity is very much in evidence here today. Indeed the ***'Huckleberry Ridge eruption'*** was the first and largest of three colossal events to have dramatically reshaped Yellowstone since the hotspot's arrival. At **VEI-**8 this phenomenal eruption ejected around 600 cubic miles of magma, blanketing most of North America in ash and plunging the entire planet into a volcanic winter. Two further explosive eruptions have created a total of three overlying calderas within the park ~ the **VEI-**7 ***'Mesa 'Falls eruption'*** some 1.3 million years ago *(which erupted around 67 cubic miles of material)*, and the **VEI-**8 ***'Lava Creek eruption'*** about 640,000 years ago *(which expelled approximately 240 cubic miles of ejecta)*. Being more recent, the Lava Creek eruption is naturally the most readily studied of these events. Geologists have revealed this to have been an immense eruption which liberated the equivalent energy of over a thousand 'Hiroshima bombs' every second. Some 360 times larger than the Mount St. Helens eruption of 1980, this last major explosive eruption of Yellowstone is believed to have generated an ash cloud that consumed over 230 square miles of land and produced fallout that would have covered ¾ of the modern **USA**.

Whilst mega-colossal eruptions tend to occur roughly every 700,000 years, present activity at the Yellowstone plateau is not just confined to hot springs and volcanic tremors. Indeed intracaldera events over the past half million years or so have included everything from smaller *(but extremely violent)* eruptions to large *(but comparatively gentle)* outpourings of lava. A number of particularly violent eruptions, for example, have occurred in the vicinity of Yellowstone Lake, notably 150,000 and 13,800 years ago, whilst a large scale extrusion of rhyolitic lava coated a significant section of the park about 70,000 years ago. Besides the periodic hydrothermal explosions and small crater-forming eruptions, the park endures continuous geothermal activity ~ most evident as features such as geysers, fumaroles and mudpots. All of this is supplied by a subterranean reservoir of magma with a volume approaching 6000 cubic miles, extending to just five miles underground. The area of Yellowstone directly above the magma chamber measures some 50 x 25 miles *(or roughly three times larger than the city of New York)*.

Today, the topology of the park is continually shifting, with pressure dynamics of the massive underground magma chamber causing the surface of the caldera to constantly rise and fall. The general trend over recent decades has been towards uplift, with rises of several inches per-year being recorded in places during the early 21st century. Prior to the next major eruption *(whenever it may be)* geothermal activity will increase, as will the intensity of local earthquakes, and the region is heavily monitored by a number of survey teams. Despite a limited understanding of the complex system that feeds this restless caldera, scientists have become increasingly adept at detecting and predicting changes in geological activity.

Although scares have been few, several significant changes have occurred at Yellowstone over the last century. In 1959, for example, an earthquake of magnitude of 7.5 *(centred in Madison Canyon on the western edge of the park)* struck with chaotic consequences. Besides setting off a flurry of geysers, it caused extensive natural damage, creating enormous fault scarps, landslides, local tsunamis and extreme air turbulence within several valleys and lakes in the surrounding mountainous region. Moving some 80 million tons of debris, the largest single landslide completely blocked a section of the Madison River creating the six mile-long 'Quake Lake' in Southern Montana. Although fatalities numbered just 28, this massive earthquake was actually large enough to have opened up new fissures within the underlying rock and trigger a super-eruption. More recently, an altogether different phenomenon effected the 'Norris Geyser Basin' *(which sits over the intersection of three major fault lines on the northern rim of Yellowstone caldera)*. Already the hottest area of the park, in 2003 the basin experienced a considerable rise in temperature as new vents began to open up ~ a sure sign of magma rising in the vicinity. Escaping gasses poisoned flora and fauna within a half mile radius, causing a large part of the Norris Geyser Basin to be closed to tourists for several months. Although these thermal disturbances gradually subsided, the welling magma had caused perceptible changes to the intricate hydrothermal system beneath the basin.

A full eruption at Yellowstone <u>will</u> happen again one day and there is always the remote chance that it could do so in near future. Should such a disaster occur, it would be totally cataclysmic and could well become be the biggest disaster in human existence. With the delicate balance of nature irrevocably disrupted, there is no doubt that all higher order life on the planet *(including our own species)* would suffer in the extreme. The survival skills of mankind would be severely tested, and the vulnerability of human society would be accentuated like never before. Indeed a Yellowstone eruption could cause the collapse of global civilisation and, with the potential to kill literally billions of people worldwide, could even push humanity to the brink of extinction.

With so much at stake, the Yellowstone hotspot has been intensely scrutinised, with computer models used to predict the outcome of numerous events that may trigger an increase in activity. 'Worst case scenario' simulations have shown the stark reality of a full eruption, highlighting the unprecedented impact it would have on the critical infrastructure of the **USA**. Given the sheer scale of the Yellowstone hotspot, it is likely *(depending on the initial ferocity)* that several eruption columns would form, merging into one as the eruption turns mega-colossal. Forecasts envisage that the collapse of such a huge column could force a lateral eruption, sending the wall superheated ash and gas outwards ~ annihilating everything within a sixty mile radius of the epicentre. Complete devastation could extend much further, with pyroclastic surges carbonising all life within an area of some 25,000 square miles. Further afield, the weight of ash fall from the eruption plume would lead to the collapse of many thousands of buildings, bring down power lines and affect the very fabric of society.

Consisting of pulverised rock and glass, volcanic ash is an extremely fine and highly abrasive material which is mildly corrosive and particularly conductive when wet. Dense ash fall can turn the daylight hours into pitch darkness, generate powerful electrical storms and stifle airflow, presenting an array of hazards. It can overheat engines, clog machinery, and short-circuit electrical components, thus crippling transportation and communication networks as well as other vital computer systems. The effects of volcanic ash and dust on human health are no less damaging, with prolonged exposure causing chronic respiratory and skeletal disorders such as silicosis and fluorosis. Given that the fallout from a full eruption of Yellowstone would blanket much of the United States, the initial death toll could well exceed half-a-million lives directly from ash-related afflictions alone. Furthermore, with prevailing winds likely to carry large volumes of ash across the Atlantic, it is quite possible that secondary ash fall could also disrupt large parts of Western Europe. In the longer term it could cause significant damage to all sorts of life essentials, from the destruction of crops and livestock to the contamination of drinking water for many millions of people.

Whilst ash fall from a supervolcanic eruption of Yellowstone could bring about enormous devastation to much of the northern hemisphere, it would not be the most widely felt hazard. A mega-colossal event such as this could poison the atmosphere with an array of toxins, substantially altering its chemistry. Noxious volcanic emissions include sulphur dioxide, hydrogen sulphide and halogen gasses *(namely chlorine and fluorine)* ~ the infusion of which could cause widespread corrosion and asphyxiation. Some compounds would be precipitated as acid rain, destroying vast swathes of vegetation, whilst others would create a veil of aerosols high in the stratosphere, deflecting solar energy and preventing direct sunlight from reaching the

Earth's surface ~ possibly for years. Indeed the biosphere would be put under enormous stress, initially from the *'greenhouse effect'* of an excessive concentration of carbon dioxide, before sulphuric acid-forming aerosols collect in the stratosphere causing the onset of a prolonged *'volcanic winter'*. With much of the Sun's energy unable to penetrate an atmosphere choked with volcanic gasses and fine debris, photosynthesis *(the most essential requirement of life on Earth)* would be stifled.

Were a full eruption of Yellowstone to completely empty the magma chamber beneath, for example, it has been estimated that global cooling could reduce temperatures in some regions by as much as 12-15°**C**. This would put higher latitudes under permanent snow cover, whilst the tropics would endure a complete destruction of equatorial rainforests and the failure of monsoons. Indeed crop failures across the globe would cause mass starvation on a global scale, with the deaths of hundreds of millions of people worldwide within a year.

Supervolcanic eruptions can also dramatically alter the composition of the oceans and bring about what is perhaps the most devastating of all natural disasters ~ an *'oceanic anoxic event'*. Anoxic events, which have accompanied most prehistoric mass extinctions, are caused by vast ocean regions becoming deficient in oxygen, thus rendering them uninhabitable to higher organisms. Indeed massive sustained volcanism wields a double-edged sword in its destruction of marine life. By ejecting vast amounts of carbon dioxide and methane into the atmosphere, it can warm the oceans enough to switch off principal current circulations and so reduce their capacity to absorb oxygen. Supervolcanoes can also contaminate water with metal-rich minerals, seeding the oceans with micronutrients and generating huge blooms of phytoplankton. Acting as an enormous carbon sink, the phytoplankton inevitably die, and strip the water of oxygen when they decay on the ocean floor ~ the acidification of which is further exacerbated by a subsequent explosion in numbers of sulphur-reducing bacteria.

The depletion of oxygen within the oceans, and their inability to oxidise excess hydrogen sulphide can invariably lead to the collapse of global food chains. Moreover, with $\mathbf{CO_2}$ no longer being taken up by the oceans, and with excessive hydrogen sulphide gas welling up from below, it could even poison the air above sea level, leading to a dramatic demise of the breathable atmosphere. The final human death toll in a disaster of such magnitude could even be marked in billions.

vii.

*(**Terrestrial calamities:** Oceanic and atmospheric disasters)*

The Earth is blanketed by a thin life-sustaining atmosphere, primarily composed of nitrogen and oxygen, with trace amounts of other gaseous elements. Extending from the surface of the planet, the atmosphere gradually thins out with altitude until its upper reaches are barely distinguishable from the all-enveloping blackness of interplanetary space. Although a sparse population of free moving particles continue to encircle the planet at over 6000 miles up in the exosphere, the ***'Kármán line',*** at an altitude of around 62 miles *(100km),* is widely accepted as being the most tangible boundary of Earth's atmosphere. Lying in the lower portion of the thermosphere, the Kármán line marks the point at which aircraft need to travel faster than the orbital velocity of the planet in order to maintain their height.

Well below this altitude exists our Earth's fragile biosphere *(or zone of life)* which permeates throughout the lower atmosphere and into the crust itself. Life has managed to take hold everywhere from the deepest ocean trenches to the highest mountain ranges. It can tolerate extreme temperatures and pressures, with specialised bacteria populating everything from boiling hydrothermal vents to freezing polar deserts. Although inactive, microbial life has even been discovered at over 25 miles high. Thrown into the stratosphere by atmospheric tides, strong weather systems or intense volcanic eruptions, these 'radio-resistant' microbes can actually survive the freeze-dry conditions and high levels of ultraviolet radiation that occur at this altitude ~ existing in suspended animation until favourable conditions prevail.

Other micro-organisms have been found in cores drilled from over three miles beneath the surface where temperatures approach 75º**C** and *(with the upper known limit of microbial life being 122º**C**)* it is believed that vast numbers of 'hyperthermophiles' thrive at even grater depths. Indeed the bulk of biomass actually exists beneath the surface of the Earth in the heated rocks of the upper-lithosphere. The greatest diversity within our planet's biosphere, however, is to be found on and around the planet's surface, with a rich variety of species existing in oceans, on land, and in the oxygen-rich air of the lower troposphere. Being so intricately bound to the environment, this portion of the biosphere is particularly vulnerable to even the most subtle changes in atmospheric conditions.

One of the most abundant compounds, and certainly the most fundamental for life on Earth, is water. Indeed, unable to exist without it, living cells comprise on average 70% water, with the water-body content of different species ranging anywhere between 55-98%. The remaining water that has not been taken up directly by living organisms can be regarded as a region of Earth's atmosphere, a vast majority of which accumulates on the crust in liquid form.

Naturally occurring on Earth in all three states *(as a solid, liquid and gas)*, water plays a vital role in the dynamics of our living planet. Around 6 million cubic miles of water is locked up in polar regions and at higher altitudes as ice sheets, permafrost and glaciers, whilst water vapour in the surrounding air accounts for about 1% of gasses present in the lower troposphere. A perpetual hydrologic cycle ensures that water vapour is continually precipitated back to the surface, with global land rainfall amounting to around 107 trillion tons annually. Over 97% of the planet's supply is present in its liquid state, with the largest bodies of water forming lakes, rivers, seas, and oceans ~ the greatest of which extends to a depth of nearly seven miles. Collectively known as the ***'hydrosphere'***, the total volume of water on Earth is around 326 million cubic miles *(or about 360 million trillion gallons)*.

Besides covering 71% of Earth's surface, water shapes the very face of the land, with the glaciation and weathering of rocks, for example, turning ancient mountain ranges into undulating hills and fertile valleys. Continually draining back to the oceans, rainwater and meltwater collects as surface runoff, carving channels which can grow into great rivers and their tributaries. It can give rise to an array of geological features from spectacular canyons and fjords, to vast alluvial plains and hidden cave networks, all of which can support unique ecosystems. The action of water is just as influential where land meets sea. Sediment transported by large rivers can build fertile deltas and estuaries, whilst elsewhere the relentless erosive power of the oceans can ceaselessly alter the coastline, sometimes in dramatic fashion.

Nor is the power of water on Earth restricted to shaping localised environments. Indeed it plays a vital role in transferring heat energy and nutrients across the surface of the entire planet. The atmospheric and oceanic circulation of water is powered by solar radiation, with the Earth's rotation and tidal forces adding to its dynamism. Atmospheric circulation is underpinned by belts of prevailing winds *(notably the 'trade winds' in the tropics and the 'westerlies' at mid-latitudes)* that 'girdle' the planet, whilst oceanic circulation is largely determined by the present positioning of the continental land masses. Both weather systems and ocean currents are naturally inclined to form vortices *(largely through the Coriolis effect)*. Pressure gradients and moisture fuel cyclones, with salinity and temperature *(thermohaline circulation)* causing ocean currents to surround several enormous gyres.

The evolution of the '***North Atlantic Subtropical Gyre****' (otherwise known as the Sargasso Sea)* illustrates the importance of water distribution to life on Earth. It resulted from the formation of a land bridge which connected North and South America roughly 3 million years ago. Besides enhancing the biodiversity of two great continents by allowing the inter-migration of land species, the *'**Isthmus of Panama**'* cut off the flow of water between the Pacific and Atlantic, completely re-routing many established ocean currents. This had a profound effect on the global climate, notably creating the ***'Gulf Stream'*** ~ a boundary current that defines the western extent of the North Atlantic Gyre. Originating in the Gulf of Mexico, the Gulf Stream travels northwards, warming the eastern seaboard of North America before meeting the cold ***'Labrador Currents'*** off the coast of Newfoundland. Causing the upwelling of these nutrient-rich Arctic waters, it has given rise to one of the world's most productive fishing grounds. From here it crosses the ocean as the *'**North Atlantic Drift**'*, bringing warm currents to much of Western Europe which, *(along with the prevailing westerlies)* keep it unusually mild in winter compared to other regions of equal latitude. However, whilst the Gulf Stream may serve to enhance Europe's temperate climate, nearer to the equator the warm waters can contrast greatly with the cold saline waters of the gyre, generating tropical cyclones which can cause widespread destruction annually throughout the Caribbean region.

Because water is present in such abundance on Earth, the energy that drives the hydrosphere is phenomenal. The most dramatic displays of power are evident as various phenomena ~ ranging from electrical storms to waterfalls, yet nothing can compare to the sheer volume of energy that is transported by the oceans. A vast majority of this is present in deep ocean currents ~ the Gulf Stream alone, for example, has a flow of water somewhere in excess of fifty times greater than all the world's freshwater rivers combined. However it is at the sunlit surface *(or photic)* zone where the sheer power of the oceans is most evident. Extending from the top of the water column to depths of no greater than 650 feet, ocean photic zones absorb vast amounts of solar radiation and atmospheric $\mathbf{CO_2}$, allowing the primary production of organic compounds by algae and other photosynthetic organisms. Yet despite being home to around 90% of all marine species, this uppermost region of ocean water experiences a turbulent relationship with the surrounding atmosphere. Indeed the tidal rhythm of the upper-oceans is continually being perturbed by atmospheric conditions above as well as seismic activity amplified through the water below.

Whilst storms and hurricane force winds can whip surface waters into a frenzy, it is, perhaps, in the aftermath of violent volcanic eruptions and submarine earthquakes that the oceans can be at their most unforgiving. Seismic activity within the oceanic lithosphere can generate tsunamis which *(although relatively unassuming in open oceans)* can wreak havoc as they approach shallow waters, causing utter devastation to populated coastal regions. The 'Indian Ocean earthquake' off the west coast of Sumatra in 2004 for example, caused a large part of the seabed to rise suddenly by over 10ft., triggering a large tsunami which killed some 230,000 people and displaced a further 1.7 million from their homes. However subduction earthquakes such as this are not the only tectonic progenitor of destructive tsunamis. Although such an event has not occurred in human history, it is known that divergent sections of the mid-ocean ridge system are periodically susceptible to collapse, having an almost immediate effect on global sea levels.

As catastrophic as they can be, underwater earthquakes are not physically capable of generating the very largest waves. *'Megatsunamis'*, several hundred or even thousands of feet high, can result from instantaneous events such as asteroid impacts, explosive volcanic eruptions or even sudden landslides. However, because of their nature, megatsunamis more often tend to occur in enclosed inland waters. Recent examples include the 1958 ***'Lituya Bay Tsunami'*** in southern Alaska which had an initial wave amplitude of 1720ft., and the 1963 ***'Vajont Dam Tsunami'*** in northern Italy which produced an 820ft. high wave ~ both of which were caused by major landslides. Thankfully modern civilisation has yet to endure a large scale megatsunami, although it has been postulated that the next significant eruption of ***'Cumbre Vieja'*** on La Palma in the Canary Islands has the potential to cause the western flank of the volcano to collapse into the Atlantic Ocean. Computer models have suggested that the resulting megatsunami could attain an initial wave amplitude approaching 2000ft. and inundate many Atlantic coastal regions. A megatsunami of such size would swamp African and European coastlines within a matter of hours, before engulfing major cities such as New York, Boston and Miami, as it sweeps several miles inland along the eastern **US** seaboard.

Whilst tectonic activity can initiate sudden but comparatively small alterations in sea level, significant long-term global changes can be brought about by supervolcanoes and major asteroid/comet impacts. Flood basalt events *(non-explosive but prolonged outpourings of lava)*, for example, can not only raise the ocean floor, but can release vast amounts of $\mathbf{CO_2}$ and methane into the atmosphere. They are known to have warmed the planet considerably in the prehistoric past, melting the cryosphere and causing sea levels to remain high for many millions of years. The most rapid falls in sea level throughout prehistory, however, have occurred in the aftermath of violent supervolcanic eruptions as well as extraterrestrial collisions. Like the debris thrown up from impacting comets, the vast quantities of volcanic ash and sulphur ejected during mega-colossal eruptions can remain suspended in the stratosphere for many years ~ raising the Earth's albedo and inducing periods of widespread glaciation. With sunlight all but obliterated for several months, global cooling is inevitable and much of the planet's water becomes locked up as ice ~ shrinking the oceans and leading to the severe arid conditions that mark most post-extinction periods in Earth's prehistory. Indeed it is true to say that major volcanic activity has brought about the most profound changes to global climates of the past.

Yet although many glacial periods throughout Earth's history have been associated with peaks in volcanic activity, volcanoes and cosmic impacts alone cannot account for the longevity of ice ages. Sulphate aerosols and fine debris thrown up by such events only remain in the atmosphere for a few decades at most, whilst ice ages themselves tend to be prolonged ~ often lasting tens of millions of years. It is true that ice sheets initially grow through positive feedback, with greater ice cover reflecting more sunlight and cooling the planet's surface further. However the onset of ice ages are also dependant on a number of other factors, not least the positioning of continental land masses, prevailing ocean currents and atmospheric composition at the time.

Ice ages themselves are not static, but undergo numerous periods of growth and decline with defining regularity. These underlying rhythmic pulses of glacial advance and retreat primarily occur as a result of astronomical variations. Interactions with the gravitational fields of Jupiter and Saturn cause the Earth's orbital eccentricity to alter, varying the mean amount of solar radiation the planet receives. When this is combined with cyclical variations in the Earth's axial tilt and precession *(which are completed every 41,000 and 26,000 years respectively)* it can have a sublime effect on the extent of glaciation on the planet. However, the fact that ice ages themselves are comparatively rare occurrences in Earth's long history suggests that the climatic effects of ***'Milankovitch cycles'*** as they are known, only become appreciable during colder climatic periods.

When geological, oceanic and atmospheric events do conspire to bring about an ice age, the consequences for life on the planet can be dramatic. The greatest of all ice ages happened towards the end of the Precambrian Aeon, at a time when life on Earth was represented by only the simplest of organisms. Occurring when the Rodinian supercontinent had begun to break up *(during the Cryogenian period beginning circa. 850 million years ago)*, this extensive ice age lasted for over 200 million years and underwent several thousand glacial pulses. During at least three of the most intense glacial maximums, ice cover straddled the globe, with even low latitudes experiencing freezing temperatures ~ leading to what has become known as the ***'snowball Earth hypothesis'***. However, despite the 'romantic' notion that the entire planet froze solid during the most severe glacial maximums, equatorial waters *(for the most part)* remained liquid, providing essential oases for primitive life to continue. Whilst a serious reduction of greenhouse gasses in the atmosphere contributed to this extreme global cooling, a total freeze of the entire planet would have completely stifled the hydrologic cycle and would have required an unrealistic rise in $\mathbf{CO_2}$ levels to have ever thawed.

This great prehistoric ice age however did come to an end. With the natural mechanisms that absorb greenhouse gasses frozen out of existence, over several millions of years sporadic volcanic activity had led to a gradual accumulation of $\mathbf{CO_2}$ and methane in the atmosphere, which eventually began to warm the planet. The 'tipping point', some 630 million years ago, occurred when continental rifting had brought about massive decompression melting within the Earth's crust, and extensive flood basalt events ensured a comprehensive thaw. Over the next 90 million years or so, populations of the hardiest organisms that had survived the prolonged deep freeze slowly recovered. By the start of the Cambrian period, some 542 million years ago, oxygenic photosynthesis *(largely by the mass of cyanobacteria that now covered the planet)* had dramatically changed the composition of the atmosphere. This new, oxygen-rich, atmosphere enabled basic eukaryote cells to undergo an evolutionary explosion that would lead to the appearance of complex multicellular organisms, including the first animal and plant phyla. There is little doubt that the ***'Cryogenian ice age'*** delayed the establishment of multicellular life by several hundred million years, whilst its demise indirectly brought about great biodiversity as opportunities to fill new niches arose.

Ice ages can be defined by the presence of extensive ice sheets at higher latitudes in both hemispheres and, although glaciation is presently in rapid retreat, we are still living in what is known as the ***'Quaternary ice age'***, Beginning around 2.58 million years ago *(at the end of the Tertiary period)*, the current ice age has encompassed over 80 glacial pulses, the greatest of which would have brought ice cover to around 30% of the Earth's land surface. The last glacial maximum *(which caused global sea levels to fall some 400ft. below those of today)* peaked approximately 18,000 years ago, whilst the present interglacial *(or warming period)* began around 11,500 years ago. Indeed the pattern of sudden glacial advance followed by slow retreat has been repeated throughout the Quaternary ice age with defined regularity. In keeping with the Milankovich cycle, glacial periods have peaked roughly every 41,000 and 100,000 years, and *(should mankind's activities not be severe enough to permanently break that cycle)* it is almost certain that another one will eventually occur.

The living Earth, of course, has been subjected to many prolonged periods of cooling and warming long before humanity came into existence. Spanning the entire Pleistocene epoch, the Quaternary ice age however is unique in that it has been crucial to the development of modern human beings ~ with glacial periods coinciding with important leaps in the evolution of our species. Indeed *Homo habilis (the earliest hominids to represent our genus)* evolved around 2.4 million years ago, shortly after the present ice age itself got underway. Climate change, in particular glacial advance, often necessitates the need for animal species to adapt to dramatic changes in the environment or face extinction, and anthropogenesis *(or human evolution)* favoured physical adaptability and greater intelligence as important traits to survive in a world of dwindling resources and increased competition. Following numerous glacial periods, by about 1.5 million years ago, *Homo erectus* had become the dominant hominid species, from which *(after a series of evolutionary spurts)* our direct prehistoric ancestors would eventually emerge.

As intelligence evolved, so the early hominids learned new techniques, such as utilising fire and animal hides for warmth, and they made greater use of tools which themselves became increasingly more sophisticated. By the time the last glacial period had begun, archaic *Homo sapiens* had become adept at innovating, thinking abstractly and planning for the future. Moreover evolutionary expansion of the human brain was also expressed through female sexual selection, creating a familial bond that in turn increased the sense of community and cultural identity. Above all, the ability to learn through rational thought, and the mastery of language to pass on knowledge and experiences *(such as hunting skills and mutual co-operation)* ensured that future generations would be well equipped to deal with climatic extremes, enabling our species to colonise every land mass on the planet. The success of *Homo sapiens sapiens* in exploiting the natural world has not been matched by any other primate species and, around 30,000 years ago, the less adaptable *Homo neanderthalensis* perished leaving ourselves as the only hominid survivors. Without glacial advance, the intellectual evolution of modern man may not yet *(if ever)* have occurred, although were such an event to happen again in the near future it would undoubtedly cripple today's global civilisation.

The amount of carbon dioxide in the atmosphere is a good indicator of global climate, with glacial periods coinciding with low $\mathbf{CO_2}$ levels. Today however $\mathbf{CO_2}$ levels are on the rise, and acute warming of the planet is of much more concern to humanity than the possibility of rapid glaciation. Throughout prehistory higher levels have been consistent with long periods of warming, and in many cases large scale 'flood basalt events' were the cause. The effects of such events can be profound. Besides pumping vast amounts of $\mathbf{CO_2}$ in to the atmosphere, flood basalt events can deoxygenate and acidify ocean waters, diminish established currents, and release methane deposits from the sea bed ~ further intensifying their warming effects.

Although the human race has never experienced life on Earth outside of an ice age, we are presently witnessing an interglacial period that is undergoing sustained global warming ~ the pace of which has begun to rapidly increase over the past few decades. This time however the warming has not been caused by volcanism but has been largely brought about by our own activities. Whilst the anthropogenic release of $\mathbf{CO_2}$ is unlikely to lead to the extreme disasters associated with flood basalt events in the immediate future, it is highly probable that, unless human activities are seriously curbed, over the coming centuries we will bring about a premature and dramatic end to the current ice age.

One direct consequence of this period of global warming is a steady and continuous rise in sea levels, with melting ice unlocking freshwater that has been held for many millennia at the poles and at higher altitudes. Perhaps the most spectacular events associated with this are the collapse of vast ice shelves that cling to the land in the polar regions. Fed by glaciers and continental ice sheets, these huge 'lips' of ice can be thousands of feet thick, and expand for hundreds of miles from the coastline. Yet, since the late 20th century, a number of ice shelves have completely disintegrated. These include the ***'Larsen B Shelf'***, an expanse of ice approximately the size of the **US** state of Rhode Island. Occupying a large embayment off the Antarctic peninsula until 2002, the Larsen B shelf had been stable since the start of the current interglacial period some 12,000 years ago. Since then a number of other Antarctic ice shelves have collapsed *(including the Jamaica-sized* ***'Wilkins Shelf'*** *in 2009)*.

Whilst the break up of an ice shelf itself does not directly contribute to sea level rise *(the ocean waters have already been displaced by its volume)* its presence acts as a brake, keeping the landlocked ice behind it from reaching the oceans. The disintegration of a shelf will therefore allow ice flow in the surrounding region to speed up. Lubricated by increasing amounts of meltwater, a glacier that feeds a perished shelf will invariably accelerate beyond the point at which annual snowfall is not enough to replace its ice, causing it to shrink or disappear altogether.

As the cryosphere recedes, so the oceans grow and, by the turn of the 21st century, sea level rise had already displaced over 100 million people worldwide. A predicted global rise in sea levels of about 10ft. by the end of the century would affect billions of people. It is highly plausible that, by then, even Antarctica's largest ice shelf *(the France-sized* ***'Ross Shelf'****)* will have either become unstable or collapsed completely. In the longer term *(over the next millennia)* the current period of global warming could even bring about the end of the Quaternary ice age itself and were, for example, the Greenland glaciers and the West Antarctic ice sheets to disappear, global sea levels would rise to around 230ft. above those of today.

Another alarming thing about the present period of global warming is that we have now passed the point beyond which temperatures will continue to rise, even if anthropogenic $\mathbf{CO_2}$ emissions were reduced to zero ~ making it virtually unstoppable. Positive feedback ensures that every year more polar ice is lost to the oceans which retain heat from the Sun more readily than when their surfaces were frozen. Where solar radiation was once reflected it is now absorbed, effectively delaying the onset of winter at higher latitudes. Consequently temperatures in the Arctic and Antarctic are rising much faster than the mean global average. As temperature differences between the polar and equatorial regions become greater, global atmospheric and precipitation patterns are acutely affected, increasing the likelihood of extreme weather around the globe.

Regardless of how much the present period of global warming can be attributed to human activity, the Earth is reacting to climate change in the same way that it has done for hundreds of millions of years. One major consequence is a gradual increase in atmospheric turbulence, causing extreme weather systems to occur more often. Indeed the intensity of typhoons, hurricanes and cyclones *(amongst nature's most destructive forces)* are directly correlated with temperature, and with the human population growing rapidly, extreme weather is affecting more people every year.

Collectively known as tropical cyclones, these enormous storm systems play a key role in atmospheric circulation, helping to dissipate solar energy across the planet. By transporting heat from the tropics to temperate latitudes, tropical cyclones are essential in regulating the global climate, yet their incontrovertible potential for destruction makes them highly unwelcome phenomena. Indeed throughout much of the 20th century considerable effort was afforded to artificially weakening, or redirecting hurricanes and typhoons without a real understanding of their importance to nature.

The most widely used system for classifying tropical cyclones is the somewhat simplistic ***'Saffir-Simpson Hurricane Scale'*** which was developed in 1971 to rate hurricanes according to the intensity of sustained winds. Placing hurricanes into five categories, the Saffir-Simpson scale was designed to illustrate the destructive potential of storms, with the fifth category reserved for those capable of causing maximum damage to human infrastructure should they make landfall. As such, a category 5 storm is defined by hurricanes that have sustained wind speeds of over 154mph. and/or create storm surges greater than 18ft., however, the scale does not take into account the physical size of a hurricane, its longevity, or the amount of rainfall it produces. Yet it is clear that as global warming continues, the strength, duration and frequency of category 5 storms is increasing, with such systems evermore likely to make landfall. Indeed the first decade of the 21st century saw more category 5 storms than at any time in recorded history.

Typhoons *(those that form in the Western Pacific Basin)* can be the largest and most intense of all tropical cyclones. Notable examples include super typhoons ***'Gay'*** *(in 1992)*, ***'Angela'*** *(1995)*, ***'Keith'*** *(1997)*, and ***'Zeb'*** *(in 1998)* ~ some of the most powerful storm systems ever recorded. The largest tropical cyclone of the 20th century however was ***'Typhoon Tip'*** which reached its peak over the ocean waters between Luzon and Guam in the autumn of 1979. At its most intense, Tip sustained winds upward of 195mph., whilst a record low pressure of 870 millibars was recorded within the eye of the storm. With a diameter of almost 1,400 miles, this enormous tropical cyclone stretched some 20° of latitude, covering an area equivalent to nearly half that of the **USA**. By the time that Tip had reached the Japanese coast, it had weakened greatly, but still resulted in many fatalities and caused considerable structural damage to numerous buildings.

Hurricanes, though generally much smaller in size than typhoons, can be no less destructive. Forming in the North Atlantic or Northeast Pacific basins, hurricanes *(like most tropical storms)* usually reach their peak and dissipate in the open ocean. However those that do make landfall, in financial terms, can be the most costly natural disasters to strike the Americas. The cost to the **US** economy from damage caused by individual hurricanes such as ***'Harvey'*** *(2017)*, ***'Ida'*** *(in 2021)* and ***'Ian'*** *(in 2022)* has run into hundreds of billions of dollars. Despite weakening considerably before making landfall, hurricanes can cause great devastation in number of ways. ***'Hurricane Ivan'***, for example, spawned 127 tornadoes as it moved northwards over the eastern United States in 2004. However the most expensive, and perhaps the most notorious, of all Atlantic cyclones was ***'Hurricane Katrina'*** whose 28ft. storm surge breached a number of levées in southern Louisiana, bringing extensive flooding to New Orleans in 2005. The second of four category 5 Atlantic hurricanes to form in this particularly active season *('Wilma' was the last and most intense)*, Katrina killed over 1800 people, whilst the cost of reconstruction alone exceeded $90 billion ~ making it one of the most expensive natural disasters to strike America.

The cost to property, however, is insignificant when compared to the cost to life. In human terms, the deadliest of all tropical cyclones are those that form over the Indian Ocean, and track towards southern Asia. Known simply as 'cyclones' in this region, like the hurricanes of Central and North America, they do not grow to the size of the typhoons that devastate the East Asian coast. Nevertheless, Indian Ocean cyclones that make landfall can kill on a truly massive scale. The worst such disaster was caused by the ***'1970 Bhola Cyclone'*** which took the lives of almost 500,000 people in the heavily populated Ganges delta region of Eastern Pakistan. A distinct lack of relief co-ordination increased resentment amongst local people towards the Pakistani government whose response to the disaster was totally inadequate. With relationships already strained, the 1970 Bhola Cyclone contributed to ethnic unrest and a subsequent civil war that would result in the formation of Bangladesh as an independent state within a year.

The Bay of Bengal is particularly vulnerable to the deleterious effects of tropical cyclones. Indeed a large number of deadly storms have hit the region over the past century, notably the ***'1991 Bangladesh Cyclone'*** which caused somewhere in excess of 138,000 fatalities. Another, ***'Cyclone Nargis'***, made landfall in 2006, just a few hundred miles to the east, killing an estimated 128,000 people in southern Burma.

Although the geography of the Indian Ocean increases the risk of direct hits from tropical cyclones, those that form here are by no means the only storms to bring death and destruction. Whilst the greatest loss of life from the 1970 Bhola cyclone arose from its massive storm surge and high winds, most of the fatalities from ***'Super Typhoon Nina'***, which crossed Taiwan and mainland China in 1975, resulted directly or otherwise from intense rainfall. Overwhelming several major dams, Nina caused severe flooding and a majority of its 210,000 or so victims were either drowned or perished over the following months from the ensuing epidemics. Flooding and mudslides were also the major causes of death from ***'Hurricane Mitch'***, which struck the Caribbean region in 1998 killing over 18,000 people in Honduras and Nicaragua.

Tropical cyclone systems may be the most extreme examples of climatic disturbance but they are certainly not the only meteorological phenomena to wreak havoc in the human world. Extra-tropical storms that form at higher latitudes, though not as powerful, nevertheless kill hundreds of people every year. Deep low pressure systems such as ***'The Great Storm' of 1987'*** brought exceptionally high winds to parts of France and Southern England, while the east coast of North America was ravaged by tornadoes and blizzards from ***'The Storm of the Century'*** in 1993 ~ both of which killed dozens of people. Like typhoons and hurricanes, the frequency of and intensity of such storms are increasing as global temperatures rise, yet climate change can have a profound effect on local weather patterns regardless of their nature. Regions of the world that experience wide seasonal variations in temperature, have seen a marked increase in the intensity of winter snow storms, with notable blizzards in Iran *(in 1972)* and Afghanistan *(in 2008)* both causing thousands of deaths. Atmospheric disasters do not necessarily result from violent weather patterns either ~ the heat wave that struck parts of Western Europe in the summer of 2003 is believed to have killed up to 70,000 people.

Perhaps the most potentially devastating of all climatic phenomena is ***'El Niño - Southern Oscillation' (or ENSO)***; the most prominent of several naturally occurring ocean-atmosphere anomalies. Causing significant variations in atmospheric pressure between the Pacific and Indian Oceans, the **ENSO** *(namely **'El Niño'** and its 'less imposing' counterpart **'La Niña'**)* can have a profound effect on the global climate, yet it represents just one in a number of periodic disturbances to effect the world's oceans.

Along with other interconnected patterns of climate variability *(such as the **'North Atlantic Oscillation'** and the **'Arctic Oscillation'**)*, the **ENSO** forms part of an intricate oceanic/atmospheric system that collectively serves to regulate the global climate. These phenomena occur at loosely defined intervals, over various time-spans. The ***'Madden-Julian Oscillation'*** *(which brings alternate periods of enhanced and suppressed rainfall across the equator)*, for example, occurs every 30 to 60 days, whilst the ***'Pacific Decadal Oscillation'*** *(which causes the relative surface temperatures of the eastern and western Pacific to shift back and forth)* enters a new phase every 20 to 30 years. El Niño, meantime, can be expected to occur approximately every three to eight years, with major events lasting a year or more. However there is growing evidence to suggest that human activity is increasing the severity and regularity of El Niño.

Like other ocean-atmosphere phenomena, El Niño is analogous to the Earth's atmospheric tides, causing subtle changes to both the surface temperature of ocean waters and sea level air pressure in a complex relationship whose effects can be sublime. It is most pronounced in the Southern Hemisphere *(where there is a greater body of water over which to propagate)* but can have a dramatic impact on the entire global climate. El Niño can also bring about significant fluctuations in established ocean currents, but it is most noticeable for causing abnormal seasonal weather conditions, with some events persisting for many months and effecting parts of the world for decades after.

The signature of an oncoming El Niño is the appearance of unusually warm waters over the central and eastern equatorial Pacific Ocean, followed by the collapse or even reversal of the easterly trade winds. This stifles the upwelling of colder nutrient-rich waters that sustain the diverse ocean ecosystems off the Pacific coast of South America. The warmer waters and lack of trade winds also serve to increase humidity, causing extensive rainfall over Ecuador and the otherwise arid coastal plains of Peru. In the wider picture, El Niño effectively causes the seasonal weather conditions of the Eastern Pacific and Indian Oceans to interchange. Whilst intense rainstorms drench parts of central South America, high pressure systems tend to form over the Western Pacific and Indian Oceans causing much dryer conditions to prevail in places such as Southeast Asia and Northern Australia. The effects of a major El Niño can percolate to other regions of the world too, resulting in abnormal weather patterns around the globe. It can bring extreme conditions to parts of North America, Africa, and even Europe, whilst cyclone genesis in the Western Atlantic, for example, is often inhibited. Indeed hurricane seasons during El Niño years tend to be less intense.

Yet, like all oscillating ocean-atmosphere anomalies, El Niño is balanced by an opposite phenomenon which is sometimes evident in the years between larger El Niño events. La Niña *(whose effects are generally weaker ~ though no less diverse)* initially occurs when warm water pools further west in the Pacific basin than normal. This causes the upwelling of cold water in the Eastern Pacific to increase, allowing surface waters here to cool even more than usual and, as a result, both prevailing equatorial winds and ocean currents are strengthened. During La Niña events, 'normal' conditions are generally enhanced *(i.e. dry regions of the world become drier and wet regions become wetter).* This ultimately increases cyclone activity in the North Atlantic ~ often raising the number of major hurricanes above the seasonal norm.

La Niña events equate to short periods of accelerated climate change, whilst El Niño can be loosely regarded as an atmospheric reaction to it ~ becoming more 'potent' as global conditions warm. The **ENSO** is an intricate part of the planet's self-regulating system, and global warming causes the abnormal conditions associated with El Niño to become more pronounced. Indeed such events have occurred at irregular intervals for at least two million years, yet until the start of the present interglacial epoch, most have been comparatively small or insignificant.

There have been thousands of El Niño events during the present Quaternary period, but few have had any lasting effect on existing ecosystems ~ with local wildlife nearly always recovering. Large El Niño events were comparatively rare throughout the recent glacial period; mainly occurring in the wake of major volcanic eruptions. The most intense series of El Niño events, however, were triggered by dramatic climate change some 11,500 years ago ~ as the ice retreated and widespread glaciation gave way to the markedly warmer world of the current Holocene epoch. By the time that this period of rapid warming had begun, early modern man had already spread to every continent, which *(compounded by the erratic El Niño conditions of the time)* put an enormous strain on many established species around the world, assuring the demise of the Pleistocene megafauna.

The El Niño events of recent decades *(like those of the early Holocene)* have become unusually prominent as the Earth's ocean-atmosphere systems react to increased global warming. Moreover, there is now a distinct trend of El Niño events occurring with greater frequency and becoming more protracted ~ causing more devastation than they have for over 11,000 years. The 1990's, for example, were beset by a succession of smaller El Niño episodes followed by the largest event on record. Indeed the El Niño of 1997-8 was possibly the most destructive since those that marked the Pleistocene-Holocene transition. The pronounced climatic oscillations during that time had given rise to a number of severe El Niño events which, along with widespread hunting, sealed the fate of fauna unable to adapt to rapid change. Now, once again mankind is exacerbating the effects of El Niño. However this time, rather than simply driving already impoverished species to extinction, human activity is altering the very mechanisms of climate change itself ~ endangering thousands of plant and animal species. Furthermore, not only are large El Niño events becoming more frequent, but ecosystems are put under increasing stress as the culmination of effects from subsequent episodes destroys natural habitats on a scale that is rivalled only by human expansion.

Major El Niño events have historically coincided with times of drought and flood, bringing about temporary ecological disasters. However the particularly strong El Niño at the end of the 20th century destroyed entire local animal populations, and threatened numerous species with global extinction. In human terms, its effects were felt hardest in developing countries ~ a number of which suffered greatly, both environmentally *(from the failure of rains or severe flooding)* and economically *(through the regional collapse of fisheries and agriculture)*. The 1997-8 El Niño directly caused over 2000 human fatalities worldwide, but far more prevalent was its environmental impact. A large number of marine ecosystems were completely devastated, with around 16% of the world's coral reefs, for example, killed off in a matter of months. On land its effects were no less stark, resulting in floods of almost biblical proportions in parts of China and East Africa, whilst the southern **US**, and much of Southern Africa suffered severe drought *(causing serious famine in the latter)*. Bringing warmer and dryer conditions to Southeast Asia, the consequences of this severe El Niño were numerous. It caused a marked increase in tropical diseases such as dengue fever and malaria, and helped to perpetuate huge fires in the rain forests of Indonesia and peat swamps of Borneo where burning continued for several years and released some 2½ billion tons of carbon into the atmosphere.

Whilst the environmental damage caused by this event was unusually high, a protracted El Niño episode from 2014-6 proved equally devastating. Coming less than two decades after the strongest El Niño on record, it too brought about extreme weather conditions around the world. Besides leading to the most active tropical cyclone season in the Pacific to date, every continent, from Europe to Australia, found itself in the grip of severe drought or intense rainfall. The possible effects of yet another severe El Niño event at this time of extreme atmospheric stress are indeterminable, but would undoubtedly be disastrous for many orders of life. With various consequences of El Niño augmented by human interference, it is, ironically, human civilisation *(relying, as it does, on so many natural resources)* that would feel the full force of such an environmental catastrophe. There is a likelihood that subsequent disasters, such as extensive wildfires and polluted waters, could threaten the existence of hundreds if not thousands of species. For humanity the collapse of food chains, relied upon to feed billions of people, would inevitably cause mass starvation and disease. Furthermore, El Niño itself has the capacity to compound the effects of other ocean-atmosphere phenomena in a way that could profoundly alter the planet's biosphere.

One such phenomenon occurs over coastal waters around the entire planet. *'Coastal wind shifts'* are becoming more prominent as global temperatures rise, and when El Niño or La Niña conditions prevail they are significantly enhanced *(particularly along the Pacific coast of North America)*. With the continents warming faster and the oceans retaining heat longer, a greater disparity in the relative temperatures of land and sea inevitably drives stronger coastal winds. As climate change continues, the temperature gradient between the two can alter dramatically, affecting the air pressure over coastal waters and causing erratic changes to the intensity and direction of local winds. By blowing warmer surface waters to different parts of the ocean, coastal wind shifts can perturb vital currents, and have a profound effect on many marine ecosystems ~ severely disrupting the delicate balance of the living oceans around the continental shelves. Furthermore these wild fluctuations are more pronounced during peak **ENSO** years.

Whenever coastal wind shifts prevent colder waters from reaching the surface, seasonal phytoplankton blooms are reduced and often delayed. This invariably fragments the food web, causing a sharp decline in fish populations, with starvation affecting everything from established reefs to migrating predators. Within these resulting *'dead zones'*, productive waters are turned into marine graveyards, and carcasses litter the seabed. Although affected ecosystems generally recover, in the months prior to the 2006 El Niño, a particularly bad series of coastal wind shifts along the Eastern Pacific caused a lasting ecological disaster. This time, rather than stifling the upwelling of nutrient-rich waters from beneath, the wind shifts blew warmer surface waters further from the Pacific seaboard of North America, causing upwelling to greatly increase. As a result, the food web in this region was overwhelmed by supercharged plankton blooms, allowing feeding crustaceans, fish and other higher order marine animals to gorge on the spring bounty. Comprising trillions of minute autotrophic organisms, the phytoplankton blooms also served to reduce $\mathbf{CO_2}$ levels in the atmosphere. However when the plankton died, they sank to the bottom of the ocean, stripping the water of oxygen as they decomposed. The hypoxic conditions *(depleted oxygen levels)* that prevailed, created a dead zone in the Eastern Pacific that caused extreme marine suffocation for over 1,100 square miles.

As climate change continues, dead zones *(both new and recurring)* appear with increasing regularity. By 2008 their numbers worldwide had reached over 400 *(a tenfold increase since they were first studied in the 1970's)*, the largest of which covered over 27,000 square miles. Although natural phenomena such as wind shifts can create dead zones, most result directly from the eutrophication of coastal waters ~ largely as a result of human activity.

Eutrophication *(an influx of excessive chemical nutrients in a body of water)* is primarily caused by the mismanagement and overuse of phosphorus and nitrate fertilisers. Whilst eutrophication is reversible, the ecology of eutrophic waters can change completely ~ with persistent dead zones in the Black and Caspian Seas, for example, seriously reducing biodiversity in the region. The discharging of untreated sewage and industrial effluent is also a major cause of eutrophication, with the Yellow Sea and the Gulf of Thailand, for example, suffering annual dead zones as a result. Another factor is the accumulation and deposition of reactive nitrogen from burning fossil fuels ~ responsible, in part, for the episodic dead zones that blight the Baltic and North Seas.

Whatever the mechanism for seeding waters with excessive nutrients, the process of deterioration is much the same, with the most extreme cases causing the collapse of entire marine ecosystems. Eutrophication encourages the growth of primary producers such as phytoplankton and algae which can form enormous blooms that both restrict sunlight to bottom-dwelling organisms and deplete levels of dissolved oxygen in the water. This can severely stifle the growth of other aquatic vegetation vital to sustaining animal populations, and can choke the waters of all higher life. Furthermore, the eventual decomposition of these harmful algal blooms can cause sea floor hypoxia to occur, and the ensuing anaerobic conditions often promote the growth of toxic bacteria ~ resulting in the creation of dead zones.

The seasonal reappearance of a massive dead zone in the Gulf of Mexico, well illustrates the devastation that such events can cause. Largely resulting from the runoff of chemical nutrients into the Mississippi River, the nitrogen-saturated ecosystems around the Gulf region have led to serious deformities amongst local fish populations, with communities of less mobile animals such as crustaceans and molluscs being completely wiped out in many areas. Furthermore toxins taken up directly from harmful algae by shellfish such as mussels, oysters and shrimps can readily work their way up the food chain and poison numerous other animal species, including our own. The situation in the Gulf of Mexico is further aggravated by human exploitation of the land, with the draining of coastal wetlands for urban expansion and agricultural development destroying the natural filtration systems that would otherwise reduce the amount of chemical fertilisers reaching the sea.

A continued increase in the number and size of dead zones along the world's coastal waters is exacerbated by various other effects, not least global warming. The key to understanding how and why ocean ecosystems react so badly to rising temperatures is down to atmospheric $\mathbf{CO_2}$ and its role in the carbon cycle. The amount of carbon dioxide in the atmosphere is a good indicator of the global climate at any given time, with ice cores providing us with the most accurate record of $\mathbf{CO_2}$ concentrations over the past 800,000 years. The carbon isotope content of ocean floor sediments *(along with scrutiny of fossilised plants)* provides the best evidence of atmospheric $\mathbf{CO_2}$ levels beyond this time.

Whilst prehistoric levels of carbon dioxide in the atmosphere were *(for the most part)* significantly higher than they are today, throughout much of the present interglacial epoch concentrations remained comparatively constant ~ varying only slightly between 260 and 280 parts-per-million. Lasting for some 10,000 years, this period of relative stability came to an end with the onset of industrial revolution, and by the mid-20th century **CO_2** levels had surpassed 300 ppm *(or 0.03% by volume)*. Rising more rapidly with each passing decade, the amount of atmospheric **CO_2** *(accounting for seasonal fluctuations)* reached 400 ppm in 2013 is currently heading towards 430 ppm *(or 0.043% of the atmosphere by volume)* ~ the highest since the 'Eocene climatic optimum' almost 45 million years ago.

For the most part, the Eocene epoch *(approx. 56 to 34 million years ago)* was marked by a period of gradual warming, the slow pace of which had little or no adverse effect on the planet's biodiversity. Indeed evolutionary adaptation enabled life to flourish and numerous new species, including many modern mammals, arose during this time. The epoch began, however, with an extreme warming event *(or spike)* which saw global temperatures rise by over **6ºC** in just 20,000 years. During the ***'Paleocene-Eocene Thermal Maximum'***, *(or **PETM**)* as it is known, atmospheric **CO_2** levels rose to in excess of 600 parts-per-million, causing a 'sudden' imbalance in the carbon cycle with disastrous consequences. A combination of events, including a rise in ocean temperature and acidity, the collapse of important ocean currents, and deep-sea anoxia led to the regional extinction of many marine species. The rate of warming that we are now witnessing is even more rapid than during the **PETM** and, with many established species unable to adapt, mass extinction is all but inevitable. Indeed it is increasingly recognised that the tipping point for widespread anoxia in the world's oceans *(given their current topology)* is likely to be reached when **CO_2** levels in the atmosphere approach 850ppm.

Although anthropogenic emissions account for less than 5% of all carbon dioxide entering the atmosphere *(the process of organic decay is by far the greatest contributor)*, the excess **CO_2** produced by human activity upsets the equilibrium of the natural carbon cycle. By 2010 around a third of all anthropogenic **CO_2** in the atmosphere was taken up by the oceans, with tropical forests absorbing just under one-fifth. Of course, as deforestation continues, the accumulation of **CO_2** puts even more pressure on the oceanic carbon sink which cannot sustain its current rate of absorption indefinitely. As the rainforests become dryer, they naturally retreat which *(along with human encroachment)* releases extraordinary amounts of carbon dioxide into the atmosphere. Moreover ocean warming lessens the ability of seawater to dissolve **CO_2** and, has the potential to severely disrupt this important natural *'solubility pump'*.

Much of the 'dissolved inorganic carbon' absorbed by the oceans takes the form of carbonic acid which serves to slowly reduce the **pH** of ocean waters. This process raises the concentration of hydrogen ions in the seawater, limiting the availability of carbonate ions used by many creatures to produce calcium carbonate for the building of shells and skeletal structures. Indeed even the smallest increase in ocean acidity can have a detrimental effect on marine ecosystems, with calcifying marine organisms particularly vulnerable. The lack of available carbonates seriously weakens the shells and exoskeletons of a huge variety of echinoderm, crustacean, mollusc and coral species that support important aquatic food chains.

As marine ecosystems come under increased stress, they in turn change the chemistry of the warming oceans ~ further contributing to the fall in seawater **pH**. Calcifying organisms, for example, play an important role in the Earth's carbon cycle, and their continued survival helps power the *'biological pump'*; a process that transports dissolved organic carbon to the depths of the ocean. The biological pump relies on sinking particulate material, with decomposing organisms and faecal matter releasing organic carbon that is returned to dissolved $\mathbf{CO_2}$ as it falls to the ocean floor. The calcium carbonate from the shells and supportive structures of dead calcifying organisms acts as a ballast, taking 'soft tissue carbon' with it, and over millions of years vast quantities of rich carbonate sediments build up along the continental shelves. Below a certain depth *(known as the 'lysocline')* however, the dissolution of calcite dramatically increases, preventing the further accumulation of carbon in sedimentary rock. Beyond this point extreme pressure, temperature and deep ocean chemistry combine to dissolve all of the remaining calcium carbonate, causing dissolved $\mathbf{CO_2}$ to persist in the water rather than being locked up in ocean floor sediments. Currently at an average depth of around 2¾ miles below sea level, the lysocline skirts the continental shelves. However as the temperature and acidity of the oceans rise so does the lysocline, with the 'under-saturated shells' from dwindling calcifier populations slowly weakening the biological pump.

Both acidification and rising temperatures directly effect another interconnected ocean phenomenon. Several thousand feet above the lysocline lies a region known as the *'gas hydrate stability zone'* where hydrocarbon gas *(mostly methane)* becomes crystallised as a permafrost within the ocean sediment. Largely formed by the microbial reduction of $\mathbf{CO_2}$, methane is found in its clathrate hydrate form as deposits in sedimentary siltstone beds along the continental shelves, and on ocean floor outcrops at depths between 1,000 and 6,500ft. Stabilised by the steady temperatures of the deep ocean and the enormous pressures of the water column above, *'methane clathrates'* often cap even larger reservoirs of gaseous methane, and are particularly sensitive to temperature change.

Because methane clathrate is essentially a gas trapped within molecules of water ice, its optimum temperature is 0º**C** and is therefore found in relative abundance in polar ice cores. It is here, where frozen temperatures allow methane clathrate deposits to form close to the surface, that global warming is most likely to bring about their destabilisation with potentially disastrous effects. By the turn of the 21st century, gaseous methane escaping from perforations in the submarine permafrost of the Arctic Ocean, amounted to several million tons every year. With an estimated 1,400 gigatons of carbon locked up as methane deposits beneath the Arctic Ocean alone, a sudden degassing of methane ice here *(and in Antarctic waters)* is recognised as being a real threat that could readily bring about abrupt climate change.

Once released into the atmosphere methane, as a greenhouse gas, is up to twenty times more potent than carbon dioxide, lowering the threshold for positive feedback *(wherein elevated levels of* CH_4 *and* CO_2 *in the atmosphere warm the oceans at an ever faster rate, which in turn liberate even more methane into the atmosphere).* The ***'clathrate gun hypothesis'***, as it has been named, envisages an explosive release of dissolved methane, akin to pulling the trigger of a gun. The expulsion of little more than 3% of all Arctic methane would be sufficient to set in motion an irreversible sequence of events that would bring about an exponential rate of warming. With warmer waters causing a greater flux in the inorganic 'solubility pump', eventually even deep water methane clathrates at lower latitudes would become unstable, leading to what has been termed the *'runaway greenhouse effect'*. Whilst it should be noted that, during prehistoric warming episodes, the sublimation of deep water methane clathrates took several millennia, the ever-quickening pace of present warming conditions is unparalleled, and a rise of 5°**C** in deep sea temperatures *(enough to release the oceans' entire methane reserves)* is likely to be reached in a matter of centuries.

Whilst the projected rise in deep water temperatures may be stark, the acceleration of atmospheric temperatures globally is far more dramatic. Indeed it is widely expected that the average global temperature will increase by around 3°**C** over the first half this century alone, and by the start of the 22nd century it is anticipated that the continents will be between 7-10º**C** warmer, with polar temperatures increasing by up to 15º**C**. There is no doubt that such a high degree of warming would seriously compromise, or even shut down, the *'thermohaline circulation'*; an important oceanic system that transports energy and nutrients around the globe.

Also known as the ocean conveyor belt system, thermohaline circulation is driven by density gradients, that are brought about by variations in ocean salinity and temperature. Perhaps the best known 'segment' is the ***'North Atlantic conveyor belt'*** which *(along with the sublime effects of atmospheric waves)*, contributes to the warming of Western Europe. In this instance, the warmer surface water of the wind-driven Gulf Stream, cools as it flows northwards, with evaporation increasing its salinity. As the colder, denser water sinks, it meets the deeper, southward-flowing currents of the Arctic Ocean, and begins a slow journey back along the ocean basin. Although some of the displaced water re-emerges in the equatorial Atlantic *(to rejoin the Gulf Stream and continue the cycle)*, most will continue towards the Southern Ocean, upwelling only when it meets colder Antarctic waters. A large volume will even join the *'Antarctic circumpolar current'* and can remain submerged for several thousand years before 'overturning' in the Indian or North Pacific Oceans forces it reappear at the surface, This process continually mixes the waters of the world ocean basins.

The ocean conveyor belt derives its power from massive dense water columns that form at higher latitudes in the North Atlantic and Southern Oceans. Warmer temperatures and reduced salinity in Arctic and Antarctic waters *(caused by the accelerated melting of polar ice)* however has the capacity to severely disrupt the formation of these dense water columns. This in turn could weaken, or even lead to the collapse of, established ocean currents that are associated with deep ocean circulation *(such as the North Atlantic Drift)*. A potential 'shutdown' of thermohaline circulation would invariably lead to stratification of the oceans, reducing $\mathbf{CO_2}$ exchange with the atmosphere thus preventing the large scale oxygenation of ocean waters. With deep water no longer being exposed to the surface, the ability of the oceans to absorb $\mathbf{CO_2}$ would diminish, adding to the positive feedback of further atmospheric warming. Besides its profound effect on the global climate, the failure of established currents would undoubtedly bring about the stagnation of numerous coastal inlets, gulfs and bays, further inhibiting the seasonal flow of nutrients *(both manmade and naturally occurring*), leading to the creation of even more dead zones.

Whatever the processes involved, it is certain that the overall warming of our planet will have a far-reaching effect on the Earth's oceans. Indeed virtually all phenomena associated with ocean warming has the potential to severely disrupt the delicate balance of today's marine ecosystems to the detriment of all life on Earth. Unless this accelerated rate of warming is curtailed, the coming century will see a further depletion of deep water oxygen, with rising dead zones underlain by permanently anoxic waters becoming an ever more common feature of the oceans. If the current trend is projected over the next millennia, all bottom ocean waters will eventually become completely devoid of free oxygen. Moreover, with the acidification of nutrient-rich waters eventually killing off important aquatic species *(such as coccolithophores and calcifying zooplankton)*, it is highly probable that the biodiversity of the oceans will suffer in the extreme. Indeed the unregulated growth of undesirable phytoplankton and toxic algae could potentially precipitate a downward spiral towards the ultimate natural catastrophe ~ an *'oceanic anoxic event'*

With most established ocean currents presently providing sufficient water circulation to continue the flow of nutrients throughout the world's oceans, seasonal plankton blooms are growing larger with every passing decade. Amongst the most numerous species are the carbon-fixing phytoplankton; a major source of atmospheric oxygen that serve to enrich the breathable atmosphere for all aerobic organisms. Although they are composed of minute *(largely single-celled)* organisms, the cumulative effects of these annual blooms are immense. They can absorb vast amounts of atmospheric $\mathbf{CO_2}$, whilst releasing more oxygen into the atmosphere than all terrestrial plant life combined. However the excessive biomass produced by these blooms can also be particularly hazardous.

When large plankton blooms die, trillions of micro-organisms sink and invariably decay on the ocean floor. They can leave behind vast carbohydrate-rich deposits on the seabed, much of which is broken down and mineralised within the sediment ~ eventually becoming fossil oil. Before petrifaction can occur however, the process of decomposition *(which involves the action of sulphate-reducing bacteria)* produces hydrogen sulphide which can readily accumulate on the ocean floor. Hydrogen sulphide occurs naturally throughout the living world *(it is, for example, present at in the guts of all mammals as a result of protein breakdown)* and, as such, can be tolerated at low levels by most species. At higher concentrations however $\mathbf{H_2S}$ is a powerful 'broad-spectrum' poison that can kill instantly.

A build up of hydrogen sulphide on the seabed has the capacity to poison vast areas of oceans, as happened during the Permian-Triassic extinction event some 251 million years ago. Then, having endured extreme volcanic activity, the oceans were warmed by excessive **CO_2**, and their capacity to absorb oxygen *(which would otherwise oxidise hydrogen sulphide)* was seriously reduced. This, the greatest mass extinction of all time, wiped out around 96% of all marine species, with the upwelling of **H_2S** and other noxious gasses from the oceans extinguishing many species of terrestrial life. Over 50% of the world's flora perished, and the extinction of so many oxygen-generating plants was disastrous for animal life, killing almost 70% of all land-dwelling vertebrates. The global extinction of such a wide range of species created a new ecological order, with the evolution of shallow plankton that metabolised **H_2S** predominating for several million years.

The toxic atmosphere of the late Permian/early Triassic would have been unbearable for most species that are in existence today. To contemplate life during this time would be to envisage a 'hell on Earth' with methane *(a highly combustible asphyxiant)* boiling from the oceans, and vast quantities of hydrogen sulphide *(a highly flammable toxin)* welling up along shorelines. Largely formed by the microbial and thermal decomposition of organic matter, the liberation of these gasses back into the atmosphere would have proved disastrous for all higher orders of life; ultimately killing all major predators, both on land and in the oceans.

Besides creating an explosive cocktail that caused huge firestorms to rip through many terrestrial habitats, excessive **CH_4** and **H_2S** would have altered the very composition of the breathable atmosphere, crippling most surviving ecosystems. Where higher concentrations of methane occurred, the displacing of oxygen from the surrounding air would have asphyxiated many land-dwelling animals whilst, even at lower concentrations, the pungent stench of hydrogen sulphide would have persisted for many years. A lethal and seductive poison at higher concentrations, the infusion of **H_2S** into atmosphere would also have caused long-term damage to the late Permian environment by depleting ozone in the lower stratosphere, and exposing surviving life to elevated levels of ultraviolet solar radiation.

Although at a comparatively early stage, we are presently at the cusp of an abrupt climate change event, the speed of which is unprecedented throughout Earth's long history. It is not unreasonable therefore to assume that the extinction event that is likely to be upon us over the next few centuries could be proportionate to the *'great dying'* over 250 million years ago. In a worst case scenario it could result in the complete loss of all vertebrate species, leaving insects and arachnids to represent the highest orders of terrestrial life. A post-apocalyptic world without mammals, birds and reptiles may be hard to accept, but it is certainly not inconceivable. Eventually, conditions could prove too hostile for even the hardiest of insect species and, as carcasses turn to bone and vegetation to dust, the relative silence of symbiotic bacteria could well be all that remains of life on Earth. Undoubtedly this would be the end of a natural era for our living planet.

viii.

(A human affliction)

For any deadly scenario to be deemed truly 'apocalyptic', many human lives need to be lost within a comparatively short time frame. Around 4 billion people died over the course of the 20th century, but the century itself was not considered to be catastrophic for humanity. Indeed this is because the human birth rate during the 20th century as a whole far exceeded the death rate. Of course if 4 billion people were killed in one fail swoop it would constitute by far the most devastating event in the existence of our species.

To get this massive number of deaths into perspective, the combined fatalities from all acts of war and genocide throughout the entire 20th century accounted for the loss of some 160 million lives *(a little under 4% of total deaths)*. Yet the sheer scale of devastation caused during the century's greatest battles and worst atrocities was such that *'apocalyptic scenarios'* unfolded in many conflicts. Human barbarity aside, a vast majority of deaths during the century were caused by 'natural' occurrences, very few of which could be considered apocalyptic in nature. Indeed most people live out their lives without ever witnessing an event of apocalyptic proportions and generally die in unexceptional circumstances. However, considering the fragile nature of our planet and the vast numbers of people now inhabiting it, the probability of a global apocalypse occurring increases with every passing year.

Since our agricultural roots, 10,000 years ago, our species has made enormous social and cultural advances. At first, the merging of familial tribes into early settlements served to protect prehistoric peoples from outside forces. But as communities grew into large cities *(which would in turn spawn powerful empires)* so our ancestors became ever more adept at exploiting the natural world around them, with trade *(and imperialism)* assuring human expansion across the globe. Over the past few millennia, great civilisations have risen and fallen, with the adaptation of knowledge and military force ensuring that each subsequent power would become mightier than those that preceded it. The art of communication *(with language and literature at its heart)*, enabled people to pass on experiences, ideas, learned knowledge and words of wisdom, whilst discovery and invention *(which blossomed following the scientific revolution of the 16th and 17th centuries)* empowered mankind, and allowed us to build increasingly sophisticated societies.

The dominance of the European powers from the 16th century ensured that Western civilisation would emerge as the cultural and economic template for a modern community of global proportions. By the 20th century the Western sciences had begotten advanced technologies that increasingly benefited many millions of people fortunate enough to live in the developed world. In the process however, mankind has become further separated from the innate inclinations that dominated the lives of our most distant ancestors and, whilst many natural hazards have been eliminated from our day-to-day lives, many new, uniquely human, ones have been created. Indeed most of the 1.2 billion people living in the developed world are totally reliant on the artificial existence of civilisation, unable to survive without 'essential amenities' that it provides.

Modern civilisation spans the entire globe. Bonded by trade and fractured by ideology, it encapsulates human co-existence and survives despite a starkly uneven distribution of wealth. Whilst the greatest benefits of today's global civilisation are, of course, reaped in the developed world, disparity is sustained by the continued sufferance of 6 billion or so impoverished people living in low and middle-income countries. It may be the largest and most powerful civilisation that mankind has ever built, but it is nonetheless very delicate.

Although most of the dangers that still threaten the world's poorest communities have been largely eradicated *(or at least controlled)* in the developed world, the relative state of comfort in which many people live is precarious. In developed countries, access to basic essentials such as food and water, adequate clothing and housing, as well as individual health care and fuel for lighting and heating are all virtually guaranteed. This is not the case in least developed, or even middle-income countries. Every year around 3.8 million people die directly from malnutrition, whilst water pollution and poor sanitation contributes to the deaths of around 3.3 million worldwide. Infectious diseases, that blight the poorest regions of the world, also kill millions of people ~ with children often accounting for the highest proportion of victims. Viral infections include gastroenteritis *(a major cause of acute diarrhoea)* which, at the turn of the 21st century, accounted for some 2.2 million deaths every year. Bacterial infections can be equally deadly, with tuberculosis, for example, causing around 1.5 million fatalities annually. Then there are parasitic diseases such as malaria, which presently kills just under a million people each year. Most victims of malaria reside in sub-Saharan Africa, a region that has taken the full brunt of the current **AIDS** pandemic. Here, as in many under-developed countries, rising **HIV** infection *(largely through a lack of education)* has greatly contributed to an annual mortality rate that now exceeds 3 million people across the globe.

Yet despite the illusory comfort and protection of modern society, even people living in the world's wealthiest nations cannot escape the natural rigors of living. Although we may have built a temporary reprieve from the wilds of nature, we have unwittingly created a new set of hazards that also incur great loss of life. Alzheimer's and Parkinson's, for example, are much more prevalent in the developed world, taking around 280,000 lives every year. Degenerative diseases such as these are generally diagnosed in older people, most of whom would not have survived so late in life had they lived in the more challenging environment of a poorer community.

One of the largest killers worldwide is hypertension *(or elevated blood pressure)* ~ a major cause of various fatal inflictions. These include heart failure, aneurysm, kidney disease, as well as cerebrovascular diseases such as stroke and ischaemia, which alone kill 5.8 million people annually. In high and middle-income countries, a large percentage of primary hypertension is caused by the 'unnatural' stresses of modern life. Furthermore, in the world's richest nations, other factors such as obesity and high cholesterol are equally significant. Both obesity and high cholesterol are also often a feature of coronary heart disease ~ the greatest killer of all. At the turn of the 21st century, coronary heart failure led to around 7.2 million deaths worldwide. A similar number die each year from respiratory diseases; in particular lower respiratory infections *(such as pneumonia)*, as well as chronic obstructive pulmonary disease *(namely bronchitis and emphysema)*. Moreover a sizeable percentage of these deaths are tobacco related.

Tobacco smoking has significantly raised the mortality rate of terminal afflictions such as heart attacks, as well as cancers of the stomach, colon and lungs. Indeed it has been estimated that as many as 100 million deaths in the 20th century were smoking related, and nicotine addiction currently contributes to approximately 5 million deaths a year. Besides cigarettes and their ilk, many other self-inflicted hazards can be just as deadly. Drug misuse and excessive alcohol consumption, for example, also increase the risk of disease, with alcohol-related deaths amounting to almost 2 million people around the world every year. Yet like smoking, *(almost 10% of tobacco-related deaths are actually from passive smoking)*, alcohol abuse doesn't just kill the primary user. The huge annual death toll from alcohol encompasses everything from chronic liver failure in long-term alcoholics to victims of fatal accidents caused by mild intoxication.

Regardless of sobriety, many thousands of deaths occur daily through accidents within the artificial 'human environment' we have built around us. Road traffic accidents worldwide take around 1.2 million lives every year ~ accounting for the highest number of unforeseen tragedies in the modern world. Moreover, the combined fatalities from everyday incidents and hazards such as these far outnumber the many millions of deaths from all the wars and atrocities of the 20th century. Yet, because these vast numbers are reached over a long period of time from numerous separate occurrences, they are generally not considered to be apocalyptic in nature.

The everyday fatalities of civilised existence contrast greatly with the truly apocalyptic *'naturally-occurring'* catastrophes that were discussed earlier in this chapter ~ none of which have *(as yet)* caused death on such a grand scale. In fact there have been <u>no</u> recorded fatalities from supernovae explosions or solar flares, for example, and no one has ever actually been killed by an asteroid or comet impact. Furthermore a mega-colossal volcanic eruption has not occurred since the rise of human civilisation *(although one was almost certainly responsible for the deaths of several million people in our prehistoric past)*. Nonetheless, the potential certainly exists for apocalyptic disasters such as these to occur, and were they to do so, they have the capacity to cause an unprecedented number of deaths.

In day-to-day life few people, however, actually contemplate the chances of an asteroid strike, or whether a supervolcano thousands of miles away is likely to erupt. More pertinent are recurring calamities such as flood, drought, famine and disease, with such disasters blighting the lives of many millions of people around the world. No country suffered more natural disasters in the 20th century than China. Home to almost 20% of the world's population, China is a macrocosm of human civilisation, and its people have endured any number of catastrophic natural disasters. Major earthquakes here killed over 100,000 people on at least three separate occasions over the course of the century, with fatalities from the 1976 Great Tangshan Earthquake unofficially reaching 650,000. Perhaps the deadliest natural disaster of the 20th century however came as a series of floods in 1931. Affecting much of Central China, several major rivers were overwhelmed when the annual spring thaw, combined with exceptionally heavy rains, inundated the surrounding plains, killing almost 4 million people in a matter of months. This came less than fifty years after an earlier flood in the region had claimed over 2 million lives, whilst a further million or so people would die in separate floods *(both manmade and natural)* along the Yellow and Yangtze River basins later in the century.

Yet even these numbers are small compared to the number of fatalities from more suffuse catastrophes such as drought, famine and disease. Between 1958 and 1961 the Great Chinese Famine, for example, took approximately 38 million lives. Largely caused by the gross mismanagement of the country's agricultural and industrial needs, the famine, though devastating was not however unique. In 1907, at a time of mass civil disorder, famine in east-central China killed some 24 million people, whilst a further 11 million Chinese died directly as the result of severe droughts in the 20th century alone. The number of victims from pandemics in China throughout the century is incalculable, but almost certainly exceeds 100 million.

After several decades of economic liberalisation, The People's Republic of China has evolved a mixed economy which has brought many millions of its citizens out of poverty ~ but not without cost. Environmental pollution, for example, now kills an estimated 760,000 people in China every year, whilst the country's growing rural-urban income gap reflects the structure of human civilisation globally. Indeed the prosperity of post-industrial cities such as Shanghai, Beijing and Hong Kong contrasts enormously with the often primitive infrastructure of China's vast rural interior. As a unified single community *(albeit under strict authoritarian rule)* human interaction and co-operation within its borders can also be seen on a global scale. What affects the people of China, affects us all.

Wherever we may live in the world, we are all at the mercy of natural disasters, and extreme weather conditions are the most common cause. As climate change continues, so heavily populated areas are increasingly likely to be effected by severe flood or drought. Meteorological disasters in wealthier regions *(such as North America and western Europe)* generally bring fewer fatalities and are more regarded in terms of cost, physical damage, and inconvenience. In poorer regions *(such as Africa and southern Asia)*, natural disasters of equal severity however can cause prolonged suffering and deprivation on a massive scale. A major cause of widespread crop failure, here both 'flood and drought' are invariably followed by famine and disease.

General starvation and a hazardous lack of sanitation following such a natural disaster is rare in the developed world. Whenever a wealthier country is beset by a localised natural disaster, its population are more likely to experience temporary shortages of particular foodstuffs, or see a rise in the value of certain luxury goods. Yet the interdependence of most sovereign nations within modern civilisation is such that an economic downturn in one region can reverberate around the world. Even the wealthiest countries are vulnerable to global recession, and any number of natural disasters have the potential to bring about a worldwide economic depression. Furthermore, a dramatic rise in the cost of living within the developed world equates to extreme discomfort for the impoverished masses existing in the world's poorest nations.

The greater any particular natural disaster may be, the further afield its effects are inevitably felt. With modern civilisation inexorably interwoven, a colossal natural disaster in any one of the world's poorest regions could readily impact the lives of hundreds of millions of individuals who benefit from living comfortably in the consumer-driven 'modern world'. Indeed a calamity of great enough magnitude, *(whatever it may be)* could be felt around the planet ~ even in distant wealthy nations that are otherwise unaffected by its destructive force. Moreover, it is entirely possible that the culmination of localised disasters could have a large enough environmental impact as to cripple 'Western civilisation' should the most affluent regions of the world no longer be able to sustain their populations. The stability of all developed countries remains as vulnerable as the civilisation they are built on and, as a species, it seems we are likely to end up the victims of our own 'success'.

Of all the apocalyptic events to have ever occurred on Earth, the most dramatic have been primarily *physical* in nature ~ where massive explosions have obliterated life instantly and destroyed vast swathes of land in a matter of seconds. On a large enough scale, the release of poisonous gasses into the atmosphere or oceans can result in a *chemical* apocalypse ~ the most severe having wiped out entire animal populations in a matter of hours. Yet not all apocalyptic disasters necessarily result from sudden physical impacts or dramatic chemical changes. Indeed any number of *biological* disasters also have the potential to decimate the global population.

The biological world *(of we are very much a part)* is the most fragile manifestation of physical existence. Life on Earth exists on a *'knife edge'* and we, like every other living species, are completely at the mercy of the elements. In fact all living organisms are susceptible to environmental changes ~ and what can prove beneficial to one species can be equally devastating for another. At the extreme, such changes can bring about a mass extinction or cause subtle genetic mutations that can alter evolutionary paths. With the collective interdependence of all species on the planet playing out within a complex *'web of life'*, the collective consequences of all environmental disasters are unpredictable. As such, there remains the slim possibility that even the most implausible of biological apocalypses could, in theory, occur even though they may now look highly unlikely to ever happen.

One such scenario is based on the idea that chemical pollutants could disrupt hormones crucial to human sexual reproduction to such an extent as to crash the global population. Indeed some proponents of this idea point to the apparent trend of falling sperm counts around the world as evidence of just such an eventuality. The concept of greater infertility amongst the human population contrasts somewhat with another possible biological apocalypse. The *'weak-gened' hypothesis* perceives of a growing threat to the population in the developed world from the millions of individuals who have been kept alive by medicine and technology. With continuing advances in medical science, huge numbers of people now survive congenital afflictions that would have once proved fatal, and are often able to go on and live full, sexually active lives. This however can be seen to have an adverse effect on the human gene pool, with a plethora of inherited genetic flaws or defects persisting amongst the general population ~ vastly increasing our susceptibility to future diseases. Another scenario is the equally controversial *(and somewhat wayward)* concept of *'dysgenics'* which suggests that a lower reproduction rate amongst more intellectual people will, over generations, weaken the average member of society, leaving the population as a whole with a serious shortage of skilled individuals able to perform higher tasks. Whilst theoretically possible, scenarios such as these appear so far-fetched as to seem laughable. However not all biologically-driven apocalypses are so unlikely to occur. By far the greatest biological threat to human civilisation is that of a global pandemic.

All living species are susceptible to disease, and our bodies are always prone to invading micro-organisms ~ the most basic and numerous forms of life on Earth. Although invisible to the naked eye, bacteria, archaea and viruses are so plentiful that they collectively account for around 98% of the planet's total biomass. Whilst only around 10,000 species of bacteria, for example, have been identified, it has been estimated that there could be in excess of 100 million separate species inhabiting every corner of the biosphere. Indeed, only a tenth of the cells in our bodies are actually our own. The rest belong to microbial flora ~ numerous species of bacteria, fungi and archaea whose presence within us is either necessary, beneficial or otherwise benign. Moreover, micro-organisms, are essential to the food web, and all complex life depends upon their existence to survive. Although a vast majority of bacteria and viruses are harmless to humans, pathogenic microbes are the most dangerous of all living entities. Indeed the death tolls from other types of natural disaster are insignificant compared to those from infectious human diseases.

Human history is peppered with devastating epidemics, with the spread of highly contagious diseases such as typhoid fever, smallpox and measles decimating native populations around the world. The most infamous pandemic in history is attributed to the plague ~ a bacterial disease which struck Asia, Europe and Africa in numerous waves between the 14th and 17th centuries. The ***'Black Death'***, as it became known, was estimated to have killed approximately 100 million people throughout the 'Old World' although it is likely that a number of other *(viral)* epidemics also contributed to this massive death toll.

Plague is caused by the bacterium *Yersinia pestis* which is primarily spread by a flea species that is normally associated with rodents such as black rats and marmots. Invading bacteria block the digestive tracts of the fleas, effectively starving them to death. Unable to appease their hunger, the infected insects embark on a feeding frenzy, continuing to gorge until gut spasms force them to regurgitate ingested blood back into their hosts, allowing the bacteria to infect new victims. When rodent populations are ravaged by infected fleas, they are invariably driven into the open where the disease can be readily transmitted to humans ~ particularly in areas of poor sanitation.

With an incubation period lasting anything from a few hours to several days, the spread of plague amongst the human population is unpredictable. During incubation of the disease, invading bacteria recombine amino acids within the host cell to produce a number of toxic proteins, and variant strains of *Y. pestis* can result in outbreaks of plague manifesting through one *(or more)* of three major types of infection. Whatever form it takes, it is highly contagious.

The most common, and best known, manifestation of the disease is ***'bubonic plague'*** which primarily attacks the lymphatic system. As it causes severe haemorrhaging of the lymph nodes, victims of bubonic plague often carry visible signs in the form of buboes ~ painful, unsightly swellings that appear around the groin and armpits. Prior to the discovery and widespread use of antibiotics, bubonic plague proved fatal in around 70% of all cases, and the 'Black Death' is historically attributed to this type of plague. The rarest, but deadliest, form of the disease is ***'septicaemic plague'*** which occasionally manifests as a progression of bubonic plague. It occurs when infected fluids drain into the bloodstream, allowing endotoxins to cause *'disseminated intravascular coagulation'* ~ a condition which leads to both ischaemia and the severe haemorrhaging of blood into surrounding organs and tissue. A particularly horrific feature of septicaemic plague is necrosis, where the victim suffers the extreme pain of their body tissue decaying while they remain alive. With a mortality rate approaching 100%, the unfortunate victims of septicaemic plague die in excruciating agony, usually within 24 hours of the initial infection.

Plague epidemics are almost always accompanied by an unmistakable smell of death, and direct contact with sufferers is extremely hazardous. The disease is virulent and highly contagious in both its bubonic and septicaemic forms, with bursting buboes, and the constant vomiting or coughing up of infected blood, releasing plague bacteria in airborne particles which are readily inhaled. It is precisely this method of transmission by which ***'pneumonic plague'***, the most infectious form of the disease, spreads. Like septicaemic plague, pneumonic outbreaks often occur as a secondary disease, manifesting from an initial bubonic infection; this time when infected blood percolates into the respiratory system. If left untreated pneumonic plague has a mortality rate of over 95% and, by causing the lungs to convulse *(thus inducing violent coughs and sneezes)* it is the most contagious of all forms of plague. In its pneumonic form, aerosolised bacteria can pass freely from person to person, infecting new victims without the need for the presence of fleas or rat carcasses as reservoir hosts.

Originating from Central Asia in the early 14th century, Black Death spread rapidly to Europe, China and North Africa. Initially carried by merchant caravans along the Silk Road, the disease soon engulfed much of Eurasia, with a plethora of trade routes *(both land and sea)* aiding its dispersal across the three continents. The first major wave of bubonic plague to strike Europe between 1347-51 killed up to 35 million people *(around 30% of the total population of the time)*. Many regions of East Asia also suffered enormously from the pandemic, particularly China where almost half of the population perished during the 1350's from either plague or the resulting famine.

Returning every few years, the effect of this continuing pestilence on medieval life was enormous. With many parts of European society in the high Middle Ages already strained by famine, war and disease *(smallpox, tuberculosis and anthrax were particularly prevalent)*, the periodic outbreak of plague was a social and economic disaster. Often preceded by the appearance of large numbers of dead rats, new outbreaks would have had an immense psychological impact on the 'god fearing' populace. In much of Western Europe and Northern Africa, it led to the widespread persecution of minorities such as Jews, lepers, gypsies and even women, who were often blamed for the suffering by an ignorant populace.

Even after an outbreak had passed through a particular region, life remained unbearable for many people. With food production crippled by serious labour shortages, most survivors of plague had to endure regular periods of starvation. Yet it was not just the poor who suffered from this recurring pandemic. It affected all echelons of society, from monarchy and nobility to landlords and merchants ~ the struggle for survival was universal. The rising price of food, along with increased taxes and rent prompted numerous peasant uprisings, and plague ultimately hastened the collapse of the feudal system in medieval Europe.

Bubonic plague would periodically ravage cities, towns and villages throughout Europe and Asia for well over three hundred years. The protracted nature of this pandemic ensured that, over many generations, the surviving population slowly built up an immunity, causing outbreaks to gradually become less severe. Sweeping through much of Germany, Austria and Bohemia during the 1680's, the last major wave of Black Death claimed several million more lives before eventually fizzling out. However the disease did not disappear completely, remaining endemic in many parts of Eurasia for several more decades. Indeed, hundreds of thousands of people would succumb to serious epidemics which would continue to break out in Northern and Eastern Europe well into the early 18th century.

The Black Death brought carnage on such a scale that many people believed that 'the end of the world was nigh'. Yet this was only the second of three documented plague pandemics to have struck the civilised world. The first, known as the ***'Plague of Justinian'***, originated in Ethiopia in the 6th century and would wipe out approximately a third of the known world population over the course of the next two centuries. Spreading into North Africa, it entered Europe though Constantinople in **CE**541 at a time when the Byzantine Empire was expanding westwards under **'Justinian I'**. This initial outbreak of the disease *(and another major wave in 588)* decimated the city and severely weakened the empire, paving the way for the Arab conquests to come. The plague is widely believed to have reached the Byzantine capital through imported grain from Egypt, and soon spread to inland Europe via a number of Mediterranean ports. Besides reducing the population of Europe by over 50%, it ravaged much of central and southern Asia, with periodic outbreaks continuing until around **CE**750. Far from disappearing, however, it remained endemic in parts of Central Asia *(from where the medieval 'Black Death' would emerge almost 600 years later)*.

Known as the ***'Third Pandemic'***, the most recent major episode of bubonic plague originated in south-west China and lasted for over 100 years. The initial outbreak in 1855 spread to most of China's southern cities after a Muslim rebellion in the Yunnan Province *(where plague had remained endemic in the rodent population)* displaced local peoples, forcing many to flee to the urban south. From China's city ports, the disease spread rapidly, with the international shipping network contributing to its worldwide transmission. Indeed this was the first time that plague would reach the Americas, making this a truly global pandemic. This time however, medical advances *(particularly the development and introduction of antibiotics)* ensured that, once it had been identified, the disease was successfully controlled before it could spread to the wider population. Nevertheless during its height, the 'Third Pandemic' was particularly virulent, becoming the number one cause of death in South and East Asia at the end of the 19th century. In 1894, for example, it ravaged Hong Kong, killing over 90% of the population, and it was here that *Y. pestis* was discovered and established as the cause of plague. It was the Indian subcontinent, however, that suffered the greatest number of casualties during this current wave of pestilence. Like Hong Kong, India was under colonial rule, and repressive quarantine regulations by the British authorities helped to focus the nation's struggle for independence. Ultimately the 'Third Pandemic' took up to 20 million lives across the world, claiming nearly half of all its victims in the northern and western provinces of India.

Outbreaks associated with the 'Third Pandemic' would continue well into the 20th century, with the last serious epidemic striking Peru and Argentina in the mid-1940's. Plague, however, persisted in a number of Pacific islands, and it was not until 1959 that the pandemic was finally considered to be no longer active. Yet the disease has not been completely eradicated and is considered by many bacteriologists to be lying in a state of dormancy. Indeed it remains endemic in several regions of the world *(noticeably South America and the western United States)* with isolated incidents sporadically breaking out just about anywhere. Thankfully the most recent outbreaks have thus far been easily contained.

Although the 'Third Pandemic' was hugely destructive, its occurrence has given scientists a greater insight into the evolution of plague bacteria. Indeed the genetic signature of *Y. pestis* is now known to have differed slightly in each of the three pandemics. What is particularly interesting is the pathogen's apparent adherence to the laws of natural selection. Whilst the 'Third Pandemic' effected every continent in the world, inherited resistance to the medieval strain of plague bacteria, *Biovar medievalis,* initially impeded its proliferation amongst the wider population of Europe. However in East Asia, where the initial outbreaks of bubonic plague occurred, a greater concentration of epidemics enabled the new subspecies, *Biovar orientalis,* to become readily established. This allowed this particularly aggressive variant of *Y. pestis (which was more likely to cause the onset of primary pneumonic plague)* to spread amongst the population. Although the infection rate of this pneumonic variant was higher than its bubonic counterpart, its greater virulence confined most outbreaks to areas of central East Asia.

By the early 20th century immunisation programs along with effective isolation of the disease prevented it from reaching the scale of destruction that the 'Black Death' had wrought. However, whilst it is readily treatable with antibiotics, the human species has not had the chance to build up a resistance this modern strain, thus we have yet to acquire any form of natural immunity to primary pneumonic plague. Indeed, of all types of plague, it is this form of the disease that remains the greatest natural threat to modern civilisation.

Whilst plague is an immensely devastating disease which has claimed the lives of hundreds of millions of people across the world, historically it is not the greatest pathogenic killer. That epithet is taken by ***'smallpox'***, a debilitating viral disease that blighted humankind for well over 16,000 years. Unique to our species, smallpox most likely originated as a mutation of monkeypox, and remained endemic in the populations of every continent *(bar Australia)* until its eventual eradication in the second half of the 20th century. The disease was caused by the 'variola' virus which, over the course of history, further mutated in response to inherited resistance. Slower to spread than plague, smallpox was easier to contain, and therefore rarely reached pandemic proportions. Nevertheless it was a highly infectious disease, and isolated outbreaks could occur just about anywhere at anytime, ensuring that localised epidemics were commonplace. Indeed the disease is widely believed to have killed almost ½ billion people over the course of the 19th and 20th centuries alone.

Responsible for taking the lives of approximately a third of its victims, smallpox could overwhelm the immune system, with many fatalities resulting from hypersensitive reactions to the disease. It was largely carried through airborne droplets containing the variola virus, and was readily transmitted during close contact with an infected person. The virus could also survive for several hours on contaminated materials such as clothing and bedding. Once inhaled, the resulting disease had an incubation period of just under two weeks, and became increasingly infectious during the latter stages. As with most pathogenic afflictions, fever and nausea were among the early signs of smallpox infection, but it was not until the first visible symptoms appeared that the victims themselves became contagious. Because the virus initially attacked cells in the mouth and throat, oral lesions were the first such signs.

Like most poxviruses, variola replicated in the cytoplasm of host cells, encoding proteins that expressed its genetic structure before rupturing the infected cells and entering the bloodstream. The virus could now begin a second phase of growth ~ multiplying in places such as the spleen, bone marrow and lymph nodes. Skin cells now became particularly vulnerable to attack from the disease, and the resulting rashes varied slightly in appearance according to the type of smallpox infection. Generally, however, they grew into painful blisters that subsided after a further two or three days. Throughout this period, victims remained highly contagious, and it was not until the last of the scabs fell off that infection was finally over. Should a victim survive smallpox, they were invariably left with any number of debilitations, ranging from pitted facial scars and skin deformities to permanent blindness and severe arthritis.

Although serious smallpox epidemics are known to have stricken the human population for many millennia, most documented outbreaks were caused by the variant *Variola major* which probably arose in Central Asia during the late 12th century. Like plague, smallpox had an enormous impact on human civilisation, and the arrival of this new strain in Europe on the eve of exploration and colonial expansion would have a profound effect on the course of history. The European population had, of course, endured repeated smallpox outbreaks for many generations, and effectively became an endemic reservoir ~ spreading this particularly virulent strain throughout the 'New World'. Whilst a large majority of smallpox victims in Europe were young children *(whose weaker immune systems made them more vulnerable to attack)*, across the Atlantic the disease was totally indiscriminate ~ wiping out more than 70% of the entire native American population between the 16th and 18th centuries. Having never been exposed to the variola virus, native Americans *(unlike their European conquerors)* had no natural immunity to this 'Old World' disease. Indeed it was instrumental in the collapse of the Inca and Aztec empires, and within a century had decimated the tribal communities of North America. Cherokee, Kalapuya, and Plains Indian populations, for example, were reduced by over 90% by the virus. Indigenous peoples elsewhere in the world faired little better, with Aboriginal, Maori and Polynesian tribes all suffering enormously from the inadvertent *(and intentional)* introduction of smallpox.

Up until the mid-20th century, there was a greater chance of contracting smallpox at some point in life than avoiding it. Throughout history, the disease was almost as prolific as it was widespread, manifesting in a number of ways. In the worst cases of *'ordinary-type*' smallpox, victims could develop respiratory complications *(such as pneumonia)* or suffer confluent rashes *(which exposed large areas of underlying dermis to infection when they detached)*. Both these developments halved the chances of survival. Other, more severe *(but less common)*, forms of the disease were also more likely to prove fatal. Both ***'malignant** (or **'flat-type') smallpox'*** and ***'haemorrhagic smallpox'***, for example, killed over 90% of their victims. Yet the disease also had less serious varieties. *Variola minor (an older strain of the virus)* had a mortality rate of less than 1%, whilst ***'modified smallpox'** (which infected previously vaccinated people)* was rarely fatal.

By the late 18th century it had been realised that exposure to certain other, less harmful, poxviruses greatly reduced the risk of contagion, and the first effective inoculations using cowpox and *(later)* vaccinia viruses were introduced. Vaccination against smallpox induced the production of neutralising antibodies which conferred immunity against the *V. major* strain. Although levels of immunity slowly diminished over several years *(requiring 'booster jabs' to maintain full protection)*, the introduction of compulsory vaccination programmes throughout the 19th century helped to eliminate the threat of epidemics in Western Europe and North America. Nonetheless, so widespread and entrenched was the disease, that smallpox continued to kill millions of people every year, elsewhere in the world, right up until the late 1960's. It took an arduous, but ultimately successful, co-ordinated global effort to completely eradicate smallpox, and by 1980 the ***'World Health Organisation'*** had declared the world and its peoples free from the disease. Subsequently, all known stocks of the virus were officially destroyed or moved to one of two high security facilities in the United States and Russia. Smallpox remains *(to date)* the only human infectious disease to be completely eliminated, however, so long as variola strains continue to be held at research laboratories in Atlanta, Koltsovo and elsewhere, it remains a potential biohazard. Indeed both the **US** and Russia have an uncomfortable history of weaponising pathogens, and the suspicion of misuse can never be completely discounted.

Plague and smallpox are by no means the only contractible diseases to have historically ravaged humankind. Indeed, despite great advances in medical science throughout the 20th century, numerous other diseases took the lives of many hundreds of millions of people around the world. ***'Measles'***, for example is another 'uniquely human' viral infection that killed over 200 million people during the last century. A highly contagious respiratory disease, measles is rarely fatal these days in the developed world, but mortality rates rise dramatically in poorer nations where persistent epidemics still kill over 150,000 people each year. The rural populations of most developing countries are at even greater risk from ***'malaria'***; a mosquito-borne disease whose annual death toll is currently some six-times higher than measles. Malaria is mainly caused by *Plasmodium falciparum*, a protozoan parasite that invades the liver and attacks the red blood cells of infected humans. Synonymous with poverty, the disease was responsible for the deaths of up to 250 million people in the 20th century alone, and remains endemic throughout the developing world ~ with the highest concentration of cases occurring in sub-Saharan Africa. Whilst fatalities occur in only around 15% of untreated cases, malaria can be extremely debilitating, and is notorious for causing severe brain damage amongst infected children.

Then there's ***'tuberculosis'***; a devastating pulmonary disease that killed around 100 million people in the last century. Transmitted aerobically through coughs and sneezes, **TB** has infected about a third of the entire world population, and continues to spread at an alarming rate. However, unlike most other pathogens, *Mycobacterium tuberculosis* largely causes latent infections which only become apparent should the disease progress to a clinically active state at a later time. Indeed many people infected with **TB**, show no symptoms at all, and most are unaware that they are even carriers of a disease from which they may never themselves suffer. Yet when active, tuberculosis *(if left untreated)* kills around half of all its victims ~ with epidemics particularly prevalent in Africa and Southern Asia. Having coexisted with humans for hundreds of thousands of years *(and other mammals even longer)*, the battle to eradicate *M. tuberculosis* has so far proven futile, with new drug-resistant strains continually evolving.

Numerous other diseases, including ***'cholera'***, ***'epidemic typhus'***, and ***'yellow fever'*** also claimed millions of lives during the 20th century. Yet not all infectious diseases were necessarily fatal, with some epidemics bringing prolonged suffering rather than probable death. Debilitating infections such as ***'rubella'***, ***'poliomyelitis'*** and ***'leprosy'***, for example, have left many millions of survivors permanently disabled and disfigured.

Human populations during the last century were ravaged by literally thousands of different infectious pathogens ~ despite continuing mass immunisation and education programmes around the world. Indeed concerted efforts to contain even the most dangerous communicable diseases during the last century were often fraught with setbacks. A lack of resources in many developing countries, for example, often compromised stringent controls during mass vaccination, allowing peripheral pathogens to mutate and evolve new strains that conferred resistance to a particular vaccine. Although modern disease prevention has ultimately caused a steady decline in mortality rates from many established diseases, almost every human pathogen has persisted, with only the poliovirus anywhere close to being eradicated.

Infectious diseases continue to blight the lives of many millions of people around the world, and the most notorious is ***'influenza'*** *(or flu)*. Affecting most birds and many species of mammal *(including human beings)*, influenza is a persistent viral disease that most people can expect to contract a number of times during their lives. It is caused by 'Orthomyxoviridae' ~ a family of **RNA** viruses of which three genera *(and species)* are implicated in the human form of the disease. The most virulent of these *(Influenzavirus A)* causes a vast majority of human flu epidemics and all known flu pandemics. More common during winter, seasonal flu epidemics result in around half a million deaths annually, but can be far more destructive when they reach pandemic level. Moreover the rapid rate at which the flu virus can mutate means that the general population will typically experience an epidemic nearly every year, as vaccinations against expected outbreaks can be rendered ineffective within a matter of months.

Influenza is most commonly spread by the coughs and sneezes of infected individuals, with airborne droplets readily carrying the disease to unsuspecting new victims. The virus will often enter the body of a new host through their eyes, nose or mouth, and is primarily caught as a result of breathing in the aerosols from a coughing or sneezing fit. However this is not the only way the disease is transmitted. It is also present, for example, in the sweat, saliva and vomit of a carrier, and can be passed on in any number of ways. Furthermore the flu virus will readily contaminate most cold non-porous surfaces for up to 48 hours ~ and for over two weeks if it is preserved in mucus. It is therefore not uncommon for the disease to spread long after an infected person has left the vicinity. Hand-to-face contact after touching an infected door handle, light switch or even money, for example, can transmit contaminant particles and enable the virus to re-infect. Indeed it is entirely possible for contaminated banknotes to continue spreading the virus for many days.

Whilst 'influenza **A**' is very resilient, like all viruses it can only replicate once it is inside a living host cell, and remains totally inactive whilst outside the body. Washing hands with antiseptic soap, and surfaces with disinfectant, is therefore the most effective way of preventing influenza from spreading further. Yet once the virus has successfully invaded a living cell and begun to multiply, the resulting disease has an incubation period of between 1-3 days, with new carriers often becoming contagious several hours before the first symptoms appear. These include nasal congestion, sore throat, persistent headache, fatigue and coughing. However, unlike the common cold *(which only attacks the upper respiratory tract)* influenza can be far more severe - infecting both the upper and lower respiratory systems and stressing the entire body. Nausea, vomiting, and fever are not uncommon, whilst more virulent strains of the virus can lead to complications such as pneumonia and even haemorrhaging of the lungs. Although serious cases of influenza can prove fatal, a majority of 'human flu' epidemics in the developed world have a mortality rate of no more than 0.1% *(with only the very young, the very old and the infirm at serious risk)*. For most people that catch the disease, symptoms persist for a week or so before the virus is eventually destroyed by their immune systems *(though it often takes children much longer to fully recover)*.

Not all types of flu however are uniquely human, and cross-species contamination can give rise to far more deadly outbreaks of the disease. Having great potential for zoonotic infection, the influenza **A** virus is what is termed a *'broad spectrum virus'*, and the most serious outbreaks of the disease actually originate from avian flu. Indeed every known subtype of influenza **A** is endemic in wild aquatic birds. Yet many species of bird that carry the virus are rarely struck down by the disease, rather they provide a natural reservoir for the virus to spread to other birds and mammals ~ often with devastating results. Avian flu outbreaks amongst the human population typically begin as isolated incidents, usually from the contagion of individuals through infected poultry. However, when a strain of avian flu comes into contact with a human variant, it is possible for either to mutate into a novel strain that is both highly virulent and readily transmitted from person to person. This process *(known as 'antigenic shift')* involves a recombination of the viral genome, and can ultimately leave populations that have built up natural immunity to most older strains of human flu, completely at the mercy of a new pandemic.

Human flu pandemics occur two or three times a century and, when they strike, devastation is by no means confined to poorer regions of the world. Named ***'Spanish flu'***, the greatest pandemic in human history occurred in 1918 and circulated amongst the human population for the next two years, spreading to all corners of the globe. Although its origin is yet to be established, the name 'Spanish flu' derives from the fact that Spain was a neutral country and not subjected to wartime reporting restrictions when the pandemic struck, so fatalities within its borders *(especially those of high profile figures)* were widely publicised. What is known is that the strain evolved directly from avian flu and rapidly transmuted into a contagious variant amongst human beings. Breaking out during a time of serious conflict, Spanish flu proved catastrophic, with some regions of the world experiencing a 20% mortality rate from the disease. Ultimately the pandemic killed around 70 million people *(over 4% of the global population)*. Indeed, it claimed as many lives in a single year as the 'Black Death' did over an entire century, constituting the greatest single natural disaster in human history to date.

Yet Spanish flu didn't simply sweep through the human population in a single outbreak, rather it struck as four waves of infection. The second wave in the autumn/ winter of 1918 was particularly lethal. Greatly exacerbated by the conditions of war, its transmission was aided, not only by the diaspora of millions of people and massive troop movements, but by widespread malnutrition and the horrific stresses of combat. Unlike most outbreaks of flu *(which are more likely to strike down the weak and elderly),* Spanish flu was particularly lethal to the young and healthy. Whilst many victims succumb to viral pneumonia, a significant proportion of fatalities resulted from *'hypercytokinemia;* an overreaction of the immune system to the disease. However within a few months of the second wave, the virus had evolved to a less virulent form and two further outbreaks *(in 1919 and 1920)* were comparatively mild. Nevertheless, key genes from the 1918 pandemic persist in the coding of many modern strains of human flu.

Spanish flu was just one in an almost endless number of manifestations of the influenza **A** virus. Having existed within bird populations for millions of years, the virus has evolved the numerous subtypes in existence today, of which ten are known to infect humans. These viral subtypes are categorised according to the coding of their surface proteins; namely *'**h**aemagglutinin'* ~ a glycoprotein that enables the virus to bind to a host cell, and *'**n**euraminidase'* ~ an enzyme involved in the subsequent release of the viral genome to infect more cells. The 1918 flu pandemic was caused by a novel strain of the virus *(classified as a subtype **H1N1** avian flu)* that quickly adapted to become transmissible between people. Indeed it is one of three subtypes that are currently endemic amongst the human population, and only **H3N2** *(the cause of most seasonal 'human flu' epidemics)* is more common. The third endemic subtype is the relatively innocuous **H1N2**, which generally produces mild forms of influenza. However new strains of human flu virus are continually emerging and, with all three subtypes also being found in both bird and swine populations, gene reassortment between these and other variants can easily lead to virulent new strains ~ putting the human population under the constant threat of a new pandemic.

In 2009 a new strain of the **H1N1** virus emerged from a farm in southern Mexico and, within months, had reached pandemic status. Resulting from a combination of bird, pig and human flu viruses, the ***'2009 swine flu pandemic'*** *(as it became widely known)* caused a little under 17,000 deaths worldwide, with Mexico itself suffering by far the greatest number of fatalities. Fortunately this pandemic became increasingly mild as it spread, and was ultimately less severe than most seasonal flu epidemics. There have of course been other, more lethal, pandemics since the 1918 outbreak of Spanish flu. In 1957 up to 4 million people were killed by ***'Asian flu'*** ~ a deadly mutation of the viral subtype **H2N2** which is commonly found in wild ducks. Originating in south-western China, Asian flu was able to spread rapidly between humans because it contained key genes from the 1918 pandemic. Indeed, although it had been almost 40 years since the outbreak of Spanish flu, **RNA** segments from the original virus were still circulating amongst many human strains ~ increasing the zoonotic potential of avian influenza considerably.

A further reassortment of the viral genome led to another pandemic the following decade. By 1968 a variant of the **H2N2** strain which had caused the Asian flu pandemic produced a lethal hybrid of seasonal human flu. The ***'Hong Kong flu'*** pandemic *(now an **H3N2** virus)* would kill almost a million people across the world, before petering out the following year. Although **H2N2** is no longer present in the human population *(and H3N2 is generally associated with comparatively mild epidemics)* antigenic shift has ensured that the legacy of Spanish flu remains very much alive. Indeed all of the most serious outbreaks of influenza amongst human beings are descended in some way from the 1918 pandemic, which has become regarded *(with certain scientific merit)* as the 'mother of all flu pandemics.

Despite the fact that human variants of **H1N1** and **H3N2** continue to show a growing resistance to the antiviral drugs used to target specific strains of flu, they do not pose the greatest 'pandemic threat'. That comes from the **H5N1** subtype; an avian flu that is almost exclusively transmitted amongst birds. Whilst it rarely affects humans, **H5N1** can lead to the most virulent of all forms of influenza, with some outbreaks exhibiting almost 100% mortality rate amongst infected poultry. With many strains of **H5N1** classed as *'highly pathogenic avian influenza'*, it has also shown to be capable of causing the deadliest outbreaks of flu amongst people.

The first recorded cases of **H5N1** avian flu in humans occurred in Hong Kong in 1997. Although only 18 people contracted the disease, a third of those infected subsequently died. Whilst there would not be another outbreak for several years, ongoing mutation of the virus amongst wild bird populations in the region gave rise to a more resilient strain which re-emerged once again as a human disease in 2003. Originating in Thailand, this new variant of the highly pathogenic strain of avian flu spread throughout much of South-east Asia over the following months, causing a number of localised outbreaks amongst the human population. Thankfully it has yet to evolve an effective means of human-to-human infection, and all cases so far have been sporadic and largely isolated. However, like most human variants of influenza, the **H5N1** strain is forever adapting, and remains an ever-present threat to human health.

Of particular concern about this strain of avian flu is its ferocity. With the site of infection for **H5N1** usually much deeper in the lungs than that of seasonal human flu, the mortality rate is much higher ~ approximately 60% of those infected with the strain are likely to die. In some of the worst effected countries *(such as Indonesia and Cambodia)* avian flu has killed over 80% of those who have contracted the disease. By the end of the decade just under 300 people had died of this highly pathogenic variant of **H5N1**. Yet it has killed hundreds of millions of wild and domestic birds globally, and the ongoing pandemic amongst avian populations has affirmed fears that excessive exposure to this fast mutating virus could initiate a catastrophic human pandemic. Indeed, despite the advances in medical science since the outbreak of Spanish flu, **H5N1** has the potential to be even more severe than the great influenza pandemic of 1918, with some estimates projecting a future pandemic with up to 150 million fatalities worldwide.

By the close of the 20th century, a number of deadly transmissible diseases had threatened to reach epidemic or even pandemic status but, thanks to both medical advances and good fortune, most had been controlled. The start of the 21st century, however saw the emergence of a new viral pathogen, and another potential pandemic.

Originating from the same family of viruses that can cause the common cold *(the most frequent infectious disease of all)*, ***'severe acute respiratory syndrome'*** *(or **'SARS'**)* had similar symptoms to influenza. With a 10% mortality rate, victims of **SARS** developed high fever and serious respiratory infections, and could become highly contagious. The first recorded cases occurred in a small farming community in the southern Guangdong province of the People's Republic of China in 2002 and, like the most lethal strains of influenza, this disease initially spread to the human population through close contact with infected animals *(in this case captive bats)*. Yet, although the **SARS** coronavirus evolved into a disease that was readily transmissible between humans, within a year it was successfully contained and ultimately resulted in fewer than 800 deaths worldwide.

The relative luck of modern civilisation in avoiding a serious global pandemic, however, came to an abrupt end in December 2019 when a novel strain of **SARS** *(subsequently named **SARS-CoV-2**)* was identified. With the first infections initially traced back to an unregulated '*wet market'* in Wuhan, China, within a month the resulting disease *(**'COVID-19'**)* would be declared a *'public health emergency of international concern'* by the '***World Health Organisation'***. Indeed, not only did **COVID-19** prove to be highly infectious, but it could be extremely debilitating for people whose immune systems were already compromised and, within three years of the original outbreak, it would go on to kill over 6½ million people worldwide. Causing many countries around the world to go into '*lockdown'*, **COVID-19** damaged the livelihoods of billions of people, and was estimated to have cost the global economy in excess of $80 trillion. Furthermore, with continuous emergence of numerous variants and sub-variants *(most with increased transmissibility)*, **SARS-CoV-2**, like influenza **A**, could readily mutate, causing **COVID-19** to become endemic within the wider population ~ despite extensive vaccination programmes in all but the world's poorest nations.

Another disease that has emerged as a direct result of human activity is ***Creutzfeldt-Jakob disease'*** *(or **CJD**)* which can be hereditary, sporadic or acquired *(through direct contact with infected tissue)*. Categorised within a group of diseases known as *'transmissible spongiform encephalopathies' (or **TSEs**)*, **CJD** causes progressive deterioration of the brain and nervous system, and is universally fatal. Unlike viral infections *(which spread by reassembling the proteins of host cells)*, the infectious agents of **TSE**s are the proteins themselves ~ more specifically 'prions'. Rigid proteinaceous structures, prions occur naturally in the neural cell membranes of many mammalian species, and are believed to play a role in the maintenance of long-term memory. But it is when they become encoded into an infectious isoform that they become deadly.

Pathogenic prions induce the abnormal refolding of other proteins, which accumulate and spread throughout the central nervous system. As nerve cells die in their millions, tiny holes appear in the cortex ~ giving rise to the typical sponge-like properties of infected brain tissue. A particularly vicious disease, **CJD** causes an array of physical and psychological symptoms *(from dementia and hallucinations to seizures and painful dysesthesia)*, and like all **TSE**s, there is no known cure. With a particularly long incubation period, **CJD** can remain hidden for anywhere between five and fifty years. However the onset of its clinical stage *(lasting just a few months)* signals certain death. Furthermore the errant prions that cause the disease are impervious to standard forms of sterilisation, and can remain hazardous for long periods ~ often persisting in the environment for several decades after an infected individual has died.

Prion diseases are not unique to humans, and can effect numerous different species of mammal. In sheep and goats, for example, it occurs as ***'scrapie'***, whilst in cattle ***'bovine spongiform encephalopathy' (a.k.a. BSE** or 'mad cow disease')* is the primary condition. In human beings **TSE**s can manifest as one in any number of diseases, including **CJD**, ***'fatal familial insomnia'*** *(FFI)* and ***'kuru'*** *(which, struck Papua New Guinea during the 1950's, and remains the only recorded epidemic of a human prion disease).* Although incurable, fatal familial insomnia and kuru are extremely rare conditions. **FFI** can strike spontaneously but is more likely to result from inheriting a mutated protein, whilst kuru is no longer an active disease, having occurred primarily in areas of New Guinea where the cannibalistic tradition of eating dead relatives had persisted. However, **TSE**s can occur to anyone at anytime and, although instances of both sporadic and familial **CJD** are also very uncommon, it is a variant form of acquired **CJD** which is of greatest concern.

Whilst the prions that cause scrapie are not believed to be transmissible to people, the same is not true of those that infect cows with **BSE**. During the 1980's, **BSE** developed in cattle which were fed on the processed remains of other cattle, and infectious prions are known to have been passed on to the human population. In the United Kingdom, where the epidemic began, over 180,000 head of cattle became infected as a result of irresponsible farming practices ~ leading to the precautionary destruction of almost 4½ million cows. A decade later, a new form of **CJD** emerged in the **UK**, with the first human fatalities occurring in 1995 directly as a result of consuming infected beef. By 2010 this *'new variant **CJD**'* had killed just under 300 people worldwide *(over two-thirds contracting the disease in Britain)*. However, whilst **nvCJD** has not reached epidemic proportions, the fear remains that the disease could possibly exist in latent form within the population at large.

Yet **SARS** and **nvCJD** are by no means the only diseases to have recently emerged as a result of human circumstance. Indeed there are numerous anthropogenic diseases in circulation *(i.e. those caused by pathogenic agents whose evolution has been 'human-induced')*. Our interference with the natural world has affected our species in many abstruse ways, but perhaps the most obvious is through the overuse and misuse of antibiotics.

The first antibiotic to become commercially available was ***'Prontosil'***, a crude sulphonamide drug that was originally marketed in Germany from 1935. It was the mass production of ***'penicillin'*** in the **US** in 1943 however that heralded a new era of effective and relatively safe antibiotics. The use of penicillin in the final years of World War **II** is believed to have saved millions of Allied lives, and the successful marketing of various derivatives in the post-war years marked the start of a medical revolution. By the 1990's more antibiotics were used each day than were prescribed throughout the entire 1940's. Surprisingly, however, over two-thirds of all antibiotics produced in America, for example, are now sold for agricultural use. The efficacy of antibiotics as medicinal treatments has been seriously compromised as a result of them being added to animal feed to promote the growth of livestock. Indeed many common bacteria that are readily passed to humans have since demonstrated resistance to agricultural antibiotics, leading to a European ban on the practice in 2003. In the **US** however, the use of antibiotics as a farming supplement remains commonplace, despite numerous lobbies to outlaw it.

It is not just intensive farming practices and infected livestock that have given rise to new human diseases. Antibiotic misuse, for example, is also prevalent in hospitals and surgeries around the world ~ vastly diminishing the potency of many such drugs. The inappropriate prescribing of antibiotics and the failure of patients to complete courses can readily facilitate evolutionary adaptations within a bacterial population. Whilst the selective pressure of an antibiotic will inhibit susceptible bacteria, if the infection is not completely killed off, the growth and contagion of hardier bacteria will continue until fully-resistant mutations arise. To this end, the widespread therapeutic use of antibiotics in hospitals has effectively caused them to become breeding grounds for new drug-resistant strains of bacteria. Indeed a plethora of different pathogenic bacteria have evolved to survive many classes of antibiotic. These multi-drug resistant organisms *(or so called 'superbugs')* include *Streptococcus pneumoniae*, *Clostrididium difficile, Mycobacterium tuberculosis* and *Escherichia coli* all of which have evolved strains that confer resistance to a growing number of antibiotics.

Perhaps the most notorious of superbugs have evolved from a strain of *Staphylococcus aureus* ~ a pathogenic bacteria that was first discovered in 1880. Commonly found in mucous membranes, as well as the nose and skin of many people, *S. aureus* is endemic in almost 30% of the human population and, for the most part, remains harmless. However if it is transmitted to susceptible foreign cells it can lead to anything from minor skin infections *(including pimples, boils and abscesses)* to life-threatening illnesses *(such as pneumonia, meningitis and sepsis)*. In 1947 *(a mere four years after penicillin was first mass produced) S. aureus* had already begun to show resistance to the 'miracle drug', and by the turn of the decade penicillin-resistant strains were becoming commonplace. By 1959 a new antibiotic, ***'meticillin'***, was developed primarily to treat *Staphylococcus* infections. Yet within two years the first strain of *'**MRSA**' (or 'meticillin-resistant' Staphylococcus aureus)* was discovered in a British hospital.

Along with *C. difficile*, **MRSA** has today become one of the most commonly identified pathogens in hospitals around the world. A wide range of antibiotics of all classes have subsequently been developed and mass produced to target the bacteria; all of which have given rise to new strains that eventually confer resistance. Indeed several strains of **MRSA** have become resistant to 'once highly effective' antibiotic compounds including ***'tetracycline'*** *(in 1991)*, ***'vancomycin'*** *(in 1996)* and ***'linezolid'*** *(in 2003)*. In the first decade of the 21st century, **MRSA**-related diseases more than doubled, and by 2010 over 14,000 fatalities were recorded annually in the **US** and **UK** alone. This number continues to rise, with multi-resistant strains of **MRSA** responsible for hospitalising a higher percentage of the population every year. It has raised fears that the bacteria could become freely transmissible outside of the hospital environment ~ causing a social epidemic. With such a potent pathogen passing readily from person to person, ***'community-acquired MRSA'*** could lead to the most horrific afflictions such as 'toxic shock syndrome', 'severe sepsis', and 'necrotising pneumonia'. Were such a strain to become endemic worldwide, it would no doubt overwhelm the health care systems of many wealthy countries, and modern civilisation would struggle to adapt.

Hospitals, by nature of design, have paradoxically been responsible for evolving new strains of drug-resistant pathogens. Indeed numerous types of bacterial and viral infections originate from ostensibly sterile environments, such as hospital wards and operating theatres. One such group of bacteria, known as ***'VRE'*** *(or* ***vancomycin-resistant enterococcus****)* includes two species, *E. faecalis* and *E. faecium*, which are commonly found living in the intestinal and urinary tracts of many people. Yet the growing antibiotic resistance of these bacteria within hospital environments has contributed to their pathogenesis and, although healthy individuals are rarely affected, **VRE** can be very dangerous to immunocompromised patients. It can cause anything from neonatal meningitis to endocarditis, as well as an array of bladder, prostate and gastrointestinal infections. What is particularly interesting about **VRE** however is its ability to pass its resistant genes to other bacteria

Another worrying development in the eternal fight against 'superbugs' was the discovery, in an Indian hospital in 2009, of an enzyme that enables bacteria to become resistant to a broad range of antibiotics including the ***'carbapenems'*** ~ the most powerful group of antibiotics yet produced. ***'NDM-1'*** *(****New Delhi metallo-beta-lactamase****)* can actually become encoded in different bacteria through a process known as 'horizontal gene transfer', creating a new generation of superbugs that express the novel gene. Indeed **NDM-1** has already shown to have jumped to other antibiotic-resistant strains of bacteria including *E. coli* and *Salmonella*. Within a year of its discovery, the **NDM-1** enzyme had been identified in hospitals in Europe and North America, leading to the fear that it could become a serious global health hazard. Of major concern is the possibility that the enzyme could pass to a strain of bacteria that is easily transmissible between patients ~ creating the potential for an 'untreatable' infectious disease to spread rapidly amongst the wider population.

Our susceptibility to new diseases is widely apparent. Indeed the greatest pandemic of the late 20th century was caused by a disease that was not clinically observed until 1981. ***'Acquired immune deficiency syndrome'*** *('****AIDS****')* was recognised as a new disease in Los Angeles, **USA**, where the first fatalities attributed to it had occurred predominantly *(but not exclusively)* amongst homosexual men ~ all of whom had died from uncommon or rare disorders. Correlating this with similar clusters of fatalities in other American cities, authorities initially regarded **AIDS** as a gay disease, originally terming the condition ***'gay-related immune deficiency'*** *(or* ***'GRID'****)*. By 1983 however, a novel retrovirus, since named ***'human immunodeficiency virus'*** *(or* ***'HIV'****)*, was identified as the single cause of **AIDS**.

HIV is transmitted in a number of ways and, once it has invaded a new host, it will infect an array of immune cells *(including macrophages, dendrites and certain* ***T-***

cells). Present, both within infected cells and as free particles within the body fluids of its host, the virus is primarily carried in the blood, semen, breast milk and vaginal mucus of infected individuals. Whilst, compared to other viruses, **HIV** is not highly contagious, infection will almost certainly bring about premature death ~ and **AIDS** has become one of the biggest killers in the world.

As sexual activity is so prevalent amongst the human population, **HIV** is most commonly spread from person to person through unprotected, penetrative sex ~ with receptive anal intercourse being particularly hazardous. Yet the risk, each time, to an unsuspecting individual of contracting the virus from an infected sexual partner in such a way is at most 1:200, with the proper use of condoms reducing the chances of contagion by a further 85%. However, because **HIV** is primarily circulated around the body within the leukocytes, infected blood *(rather than seminal fluid)* is the principal contaminant. It follows, therefore, that the sharing of needles provides another major route of transmission for the virus, making it comparatively common amongst intravenous drug users. Yet even this practice only carries around a 1:150 chance of someone acquiring **HIV** directly from an infected needle.

Far more devastating is the *'vertical infection'* of a mother passing the virus to her offspring, either through pregnancy, labour or childbirth itself. Indeed the unfortunate children born to women who are **HIV** positive, are likely to have a 1:4 chance of inheriting the virus from their mothers. However the most direct mode of **HIV** transmission is through transfusions and other surgical procedures that inadvertently use contaminated blood products. Recipients are almost certain to acquire the virus themselves and, before the introduction of effective screening procedures in the developed world, tens of thousands of haemophiliacs contracted the virus after receiving blood from infected donors. With unhygienic practices still rife in poorer countries, it is estimated that 2% of all new cases of **HIV** continue to be contracted this way.

The mean survival rate from initial **HIV** infection to terminal decline from **AIDS** is close to 10 years. As the disease progresses, the viral infection undergoes four main stages, the first being an asymptomatic *'incubation period'* which typically lasts between two and four weeks. This is followed by a secondary stage ~ a period of *'acute infection'* lasting approximately a month, when the virus spreads rapidly throughout the body and a carrier is at their most contagious. At this stage an infected person would experience typical viral symptoms including, rashes, sore throat, swollen glands, fever and general malaise. These non-specific symptoms are often not recognised as **HIV** infection, and many sufferers remain unaware that they have been infected. The virus then undergoes a *'latency stage'* which can last anywhere from under a month to over 20 years depending on the physical health of the carrier. During this time the virus gradually accumulates within the lymphatic system until the depletion of healthy immune cells *(more specifically **CD4+ T** 'helper' cells)* reaches a critical level. At this point the carrier will invariably develop *'full-blown **AIDS**'* and, without anti-retroviral treatment, will most likely die within a year.

The onset of **AIDS** is usually accompanied by rapid weight loss, respiratory infections, rashes and ulcerations. These first symptoms eventually give way to more serious conditions, with victims often succumbing to pulmonary diseases such as pneumonia and tuberculosis. However **AIDS** can bring about an array of different infections caused by numerous bacteria, viruses, fungi and parasites that would otherwise have been resisted. By seriously weakening the immune system, **AIDS** itself does not actually kill, rather it renders the body defenceless against any number of opportunistic infections and malignancies. Terminal afflictions often take the form of neurological disorders, gastrointestinal diseases, and tumours ~ the prevalence of which can depend greatly on the victim's environment.

Retrospective prognosis has revealed that **HIV** had been circulating amongst the human population for many decades before its discovery in 1983, and probably reached the **US** *(where it was first diagnosed)* sometime in the mid-1960's. Further **HIV** testing of preserved tissue and blood from victims of uncommon diseases and unexplained cancers has shown that people have been dying from **AIDS**-related illnesses since at least 1959, with growing numbers of fatalities, since attributed to the disease, evident throughout the 1970's.

Two major types of **HIV** are today known to be endemic amongst the human population ~ both of which originated on the African continent. Whilst type ***'HIV-2'*** is less infectious and still generally confined to West Africa, ***'HIV-1'***, *(the first type to be identified)*, is slightly more virulent and far more widespread. Because it has such a fast replication cycle, **HIV-1** in particular has a high genetic variability within the human population, and has evolved numerous variants. Unlike most viruses, infection from one strain does not confer immunity to another ~ in fact the versatility of **HIV** is such that different strains readily mutate into 'recombinant forms'. This means that someone who is **HIV** positive and acquires it again after being re-exposed to a different subtype of the virus, will most likely develop a 'superinfection' ~ hastening their progression towards **AIDS**.

It is widely believed that **HIV** first crossed to the human population in equatorial West Africa as an adaptation of ***'simian immunodeficiency virus'*** *(SIV)* sometime in the early 20th century. **HIV-2** *(which was in fact the first type to emerge in humans)* most likely originated from the Sooty Mangabey ~ an old world monkey which has long since evolved a commensal relationship with the virus. Indeed **SIV** is endemic in many African primates and has been present in some species for well over 30,000 years, allowing them to adapt to its presence. Almost all mangabeys, for example are carriers of **SIV** but rarely develop simian **AIDS**. However, because the virus has only been present in our own species for a matter of decades, by comparison a mere 0.5% of infected humans will remain **HIV** positive without developing the clinical symptoms of **AIDS**. Though few in number, these *'long term non-progressors'* have inherited **T**-cell receptor mutations that forestall the advancement towards **AIDS**, and their presence is invaluable to the development of 'entry inhibiting' antiretroviral drugs.

HIV-1 is believed to have crossed to humans as an adaptation of an **SIV** strain that is endemic in common chimpanzee populations *(a species which has itself only carried the virus for little more than a century and, like humans, has not yet formed adaptive immunity to the disease)*. The most virulent strains of **HIV-1** probably emerged during the late 1930's, most likely crossing the species barrier as a result of human expansion. By encroaching further into the rainforests, human populations invariably had greater contact with primate carriers, and exposure to **SIV** became increasingly common when capturing or slaughtering infected animals for bush meat. The virus did not initially spread to the wider population, with most infections being limited to the hunters and butchers who had direct contact with diseased animals. Indeed it is likely that many thousands of **SIV** infections occurred before a particular virion mutation allowed the virus to survive by becoming readily transmissible between humans. However, once **HIV-1** had taken a 'foothold' in local populations, greater exposure over following decades allowed it to spread rapidly. At first, primitive inoculations against smallpox and other devastating diseases provided a particularly effective mode of transmission for the virus, with the use of un-sterile needles in mass vaccinations a practice that is still widespread throughout Africa. From here sexual transmission spread **HIV** to the wider population, ultimately leading to the current **AIDS** pandemic.

There have, of course, been a plethora of alternative hypotheses for the introduction of the virus to humans, Indeed the misguided belief that **HIV** originated as a series of **US** military experiments still holds popularity in some quarters of society. The notion, for example, that it was genetically engineered to target Black Africans and/or homosexuals persists ~ with the idea of deliberate infection being irresistible for many conspiracy theorists. Perhaps the most controversial theory was that **HIV** was introduced to humans inadvertently when experimental live preparations from infected monkeys were given to almost a million people as a vaccine against poliovirus throughout the Belgian Congo during the late 1950's. Thankfully all of these unsound theories and fallacious ideas have since been totally discredited by the international scientific community. Yet there is even a persistent body of **AIDS** denialists who consider that **HIV** is not the direct cause of the disease at all. This too is false. However, the idea dominated the ill-conceived health policies of the South African government for almost a decade at the start of the century, leading to hundreds of thousands of additional infections in the country during this time.

How ever **HIV** originated, it has proven to be totally devastating. At the turn of the 21st century **AIDS** had claimed the lives of almost 25 million people across the world, and by the early 2020s that figure had risen to 40 million. In 2010 alone there were 3.5 million **AIDS**-related deaths reported around the world. Despite numerous high profile campaigns to bring about awareness throughout the developed world, widespread ignorance of the disease continues. Yet it is in the poorer communities of the developing world where the disease has taken the greatest toll, with over two thirds of all **AIDS** victims living in sub-Saharan Africa. **AIDS** often carries enormous social stigma here, leading to victims and their families suffering great prejudice. Moreover the disease has put an enormous strain on the economies of the developing world, increasing poverty and destroying whole communities. One of the worst affected countries is South Africa where one person in eight is **HIV** positive, and the infection rate amongst adults is over 20%. By the end of the first decade there were up to 15 million **AIDS** orphans living throughout the African continent and, with no cure available in the foreseeable future, **AIDS** will continue to bring misery and despair to millions.

Yet the wealthier societies of the developed world are faced with a completely different predicament. Here expensive anti-retroviral drugs are available, which can suppress the virus and hold **AIDS** at bay for up to 50 years. The result is that, whilst there are likely to remain less **AIDS-**related deaths in developed world, societies will become increasingly burdened by the growing reservoir of **HIV** carriers amongst the general population.

In the early days of **AIDS** research, the idea that the viral pathogen responsible for this new disease could become more contagious as the number of infections rose was of major concern. However, whilst infection rates have certainly increased as populations have endured more carriers, there is no evidence to suggest that people today can acquire **HIV** more readily through the usual modes of transmission. Perhaps the greatest fear at the time *(and one that persists within pockets of society where pseudo-scientific miseducation predominates)* was that the disease had the potential to mutate and become transmissible in aerosol form, making it as contagious as influenza or the common cold. Of course this scenario is highly unlikely as the evolution of **HIV** would have to counter several laws of natural selection.

Perhaps the most basic evolutionary rule of pathogenic microbes is that, under natural conditions, their virulence decreases as they become more transmissible. If, for example, the common cold *(the most frequent infectious human disease)* were to be deadly in 99% of all cases, the virus's comparatively short incubation period and subsequent infectiousness would not allow it to spread as readily as it does. Were this the case, the common cold would more likely kill most of its victims before they could contaminate more people, thus reducing the potential number of infectious carriers. Less virulent strains of the cold virus would therefore be more successful and so eventually predominate.

It follows that the most widespread diseases have evolved short incubation periods and low pathogenicity, allowing them to replicate faster and infect more new hosts. Indeed most pathogenic bacteria and viruses would ideally evolve towards a fully commensal relationship with their hosts. This evolutionary trend can be seen in the bacteria that cause syphilis and tuberculosis, as well as the measles virus - all of which were once more virulent but not quite as infectious as they are today. **HIV** meantime, has proven highly successful as a virus with a long period of clinical latency and, unless it were purposely engineered to do so, **AIDS** is highly unlikely to become more contagious without becoming less deadly. It is precisely this evolutionary rule that keeps some of the deadliest of all diseases from reaching pandemic status.

One of the most virulent of all pathogenic microbes is ***'Ebolavirus'*** which was first identified in Central West Africa during an initial outbreak in 1976. A lethal and extremely painful viral disease, ***'Ebola haemorrhagic fever'*** is highly contagious, and has a mortality rate of up to 90% *(dependant of strain of Ebola that causes the outbreak)*. Although it does not confer resistance to new drugs as readily as more common pathogens *(such as those that cause **TB** and malaria for example)*, Ebola can wreak havoc in the communities where it arises. However, with a relatively short incubation period, widespread infection is rare as victims of the disease experience a fast onset of symptoms which limit the ability of the virus to infect multiple hosts. Indeed sick individuals are soon incapacitated or often die before they are able to spread the contagion further.

From the same family as Ebolavirus *(and almost identically structured)* is ***'Marburgvirus'*** which, like its taxonomic cousin, can infect all species of primates. ***'Marburg haemorrhagic fever'*** can be equally devastating and, although the mortality rate amongst infected humans varies in different outbreaks, viral infection is fatal for approximately 60% of people that are misfortunate enough to contract the disease.

Both Ebola and Marburg most likely originated in African fruit bats, several species of which provide a natural reservoir for the diseases. Although the bats themselves remain completely unaffected, the viruses are shed in their saliva, contaminating discarded fruit that can be stumbled across by foraging apes and monkeys *(with gorillas proving to be particularly susceptible)*. Contact with diseased primates has invariably enabled the viruses to pass to our own species. From here, both the Ebola and Marburg viruses can spread between humans through infected body fluids. Although not transmitted aerobically as freely as plague or influenza for example, they can be passed on to new human hosts through close contact with victims. With either virus present in the excreta, vomit and blood of a carrier, contaminated droplets can permeate the conjunctiva or be readily inhaled by an unsuspecting carer.

Ebola and Marburg are just two of many pathogens that can cause *'viral haemorrhagic fever' (or **VHF**)*. However the mechanisms of pathogenesis vary considerably, and with most other causative viruses the manifestation of a viral haemorrhagic fever occurs only in more severe cases of infection. Yet when it does arise, besides causing the characteristic fever and bleeding disorders, **VHF** itself can progress to any number of serious syndromes. The most common afflictions associated with viral haemorrhagic fevers include severe hypotension, organ inflammation and dysfunction, cardiovascular shock. encephalitis and various neuropsychiatric conditions.

Whilst a majority of **VHF** pathogens originate from sub-Saharan Africa, many can cause sporadic and often vicious outbreaks to occur almost anywhere in the world. Although serious epidemics of **VHF** are comparatively rare outside of tropical and subtropical regions of Africa, Asia and South America *(where they remain endemic)*, some of the more adaptive viruses have successfully assimilated local species that inhabit more temperate climates ~ using them as 'amplifying hosts' that can in turn spread the viruses to human populations living at higher latitudes.

Numerous other pathogens *(including the **'Rift Valley virus'**, **'West Nile virus'** and **'dengue virus'**)* also have the potential to cause viral haemorrhagic fever. With mosquitoes being the primary vectors for diseases such as ***'Rift Valley fever'***, ***'West Nile fever'***, and ***'dengue fever'***, human activity has inevitably hastened their proliferation across the continents. Although infections from these viruses are less likely to prove fatal, they are far more widespread than the more lethal Ebola and Marburg. Population expansion, modern transportation, polluted water and global warming amongst other things have all contributed to a rapid increase in cases of diseases such as these over the past few decades. However only a small minority of infected individuals succumb to the more serious secondary complications associated with **VHF**s. Rift Valley fever, for example, is mainly associated cattle but can also infect humans, and is now prevalent throughout the entire African continent ~ though it is rarely fatal. West Nile virus meantime is even more widespread. Capable of infecting a range of both domestic and wild animals as well as humans, its propagation by various bird species *(which largely remain asymptomatic)* enables it to re-infect feeding mosquitoes, and transmit the disease to local animal populations in almost every continent. Indeed West Nile virus is now endemic in some parts of North America, Europe and Asia. The most common viral disease capable of progressing to a haemorrhagic fever however is dengue, which presently infects up to 400 million people around the world every year. Yet, like the other widespread viral pathogens, dengue infection rarely progresses to a full haemorrhagic fever. Nonetheless with such a high infection rate, by the mid-2010s it was causing around 40,000 deaths annually ~ a figure that continues to rise.

Perhaps the most notorious virus associated with **VHF** outside of Africa is the ***'yellow fever virus'***. Another mosquito-borne disease, ***'yellow fever'*** was introduced to South America in the late 15th century with the start of the Atlantic slave trade. Over the following centuries it spread to other continents causing major epidemics as far afield as southern Europe and North America, killing hundreds of thousands of people every year. The advent of an effective vaccine in the 1930's eventually restricted it to tropical and subtropical Africa and South America where it remains endemic. Today however yellow fever is regarded as a re-emerging disease, with the number of outbreaks increasing with each passing decade. By the late 2010s the disease was responsible for around 50,000 deaths, mostly in the largely unvaccinated urban populations of Africa. Fortunately 85% of people who contract yellow fever will only experience mild symptoms, however the rate of survival is greatly reduced for those victims of the disease unfortunate enough to enter its more toxic phase.

Not all of the 'widespread' **VHF**s are transmitted by mosquito bites. The ***'Lassa virus'*** *(which can give rise to* ***'Lassa haemorrhagic fever'****)* is endemic throughout West Africa, where it is often present in the excreta of common rodents. In areas of poor hygiene, human contact with *(often aerosolised)* rat excrement has caused outbreaks of Lassa fever to be relatively common. The virus can spread from person to person through infected body fluids and excreta, and can devastate unprotected local communities. Most infections originate in the respiratory tract, where the virus undergoes a process of rapid replication and, should the disease progress, it will attack every tissue in the body. However, whilst almost ½ million people contract yellow fever every year, the mortality rate from the disease is only around 1% of those infected.

Despite the fact that most of the viral infections that can lead to haemorrhagic fever generally result in only mild symptoms, the causative viruses remain of great concern.

VHFs are ultimately caused by four distinct families of viruses, all of which contain genera that can readily spawn new pathogenic serotypes ~ and there is always the fear of further mutation. Moreover, it is widely known that **VHF**s can be readily aerosolised, and have the military potential for adaptation as effective biological agents.

Every year a multitude of new diseases are discovered, whilst novel strains of known pathogenic microbes continuously emerge in different communities around the world. Many new diseases are comparatively mild and can go undetected *(or are otherwise misdiagnosed)*, but every so often virulent new strains cause serious outbreaks that can reach epidemic and even pandemic proportions. Numerous variants of established and hitherto uncommon pathogens are most often unwittingly carried by people who can potentially spread new diseases to the wider population without knowing. Sometimes however, the further contagion of particular pathogens can be intentional.

The most direct source of new bacterial and viral strains are 'biological research establishments' of which there are several thousand across the globe. Despite varying levels of security, numerous biotech and pharmaceutical company laboratories, academic research centres and defence facilities have been guilty of releasing potentially hazardous microbes into the environment. Indeed, most micro-organisms are so adaptable that full containment can never be 100% guaranteed.

Perhaps the most notorious case of *'biological pollution'* resulted from the accidental release of weaponised anthrax spores from a military compound near the 'closed' Russian city of Sverdlovsk *(now Yekaterinburg)* in 1979, killing at least 100 people. Although anthrax is highly lethal, fortunately it is not contagious and the outbreak was soon isolated. During the Cold War years however, vast quantities of various biological agents were manufactured and stockpiled in the **USSR**, and the Sverdlovsk leak was just one of many lethal accidents across the country. Over the years ***'Biopreparat'*** *(the clandestine Soviet agency responsible for bioweapons research and development)* successfully covered up a number of accidental outbreaks involving virulent new strains of diseases including smallpox, Marburg and tularaemia.

At the height of the Cold War most major world powers had large networks of bioweapon research and development facilities within their borders. Such was the degree of mutual mistrust and paranoia between the two contrasting ideologies that the intentional release of various biological agents into the local environment was relatively commonplace. Moreover it was not just the **US** and the **USSR** that were guilty of carrying out unethical biological experimentation on their own populations. In the **UK,** for example, the microbiological research establishment at ***'Porton Down'*** in Wiltshire was responsible for carrying out a series of germ warfare simulation trials across the counties of Dorset, Devon and Somerset during the 1960's and 70's, employing everything from *E. coli*, to *Bacillus globigii* as testing agents. In the so-called *'Lulworth experiments' (finally publicised in the 1990's)* an array of different aerosolised bacteria were periodically sprayed from ships off the coast of Lyme Bay in Southern England in order to determine how biological agents would behave and survive under different environmental conditions. As a result raised numbers of miscarriages, stillbirths and congenital diseases were recorded amongst exposed populations *(particularly in parts of south Dorset)*.

Many biological weapons research programs in the United States were even more vigorous and indiscriminate. Here, germ warfare experiments were co-ordinated from ***'Fort Detrick'*** in Maryland, and resulted in a number of pathogens being deliberately released onto American soil. In the mid-1950's, for example, military aircraft released millions of mosquitoes infected with strains of yellow fever and dengue fever over parts of Georgia and Florida, whilst coastal communities around the Tampa Bay area of Florida were exposed to clouds of *Bordetella pertussis* leading to a serious outbreak of whooping cough. These and other irresponsible experiments either side of the iron curtain caused an indeterminate number of deaths amongst the civilian populations that these governments purported to protect.

Throughout the Cold war deadly diseases such as anthrax, Ebola, plague, cholera and typhus were weaponised on a massive scale and, with advances in biotechnology, ever more virulent and drug-resistant strains were created. The direct genetic manipulation of pathogens had really begun in 1972 when **DNA** strands from a monkey virus and lambda virus were successfully recombined, and within a year the first antibiotic-resistant *E. coli* bacterium had been created. As the genetic sciences have become more sophisticated, the ability to manipulate microbial extremophiles has allowed military scientists to create particularly robust transgenic variants that could persist in various different environments. These deliberately-engineered pathogens provided the Cold War powers with an array of wholly unethical bioweapons designed to target perceived enemies in specific ways. Botulinum toxin, for example, was now recombined with desired proteins which, when aerosolised, created a novel delivery system for a range of horrific weapons, Another widely adapted pathogen was diphtheria toxin which could, for example, be added to *Y. pestis* in order to reduce any natural immunity to plague that a targeted 'enemy' community may have acquired.

Despite international protocols and conventions that forbid offensive bioresearch, attempts to engineer bacteria and viruses with increased virulence and infectiousness has continued unabated. Indeed the United States, Israel, Russia, China and North Korea all continue covert bioresearch operations that could be considered to have military benefits. This continuation of 'aggressive biotechnology' *(often under the guise of benevolent medical research or vital national defence programs)* ultimately increases the danger of causing wider genetic contamination ~ even if the resulting weapons are never used in anger. Not only does such research run the risk of irrevocably polluting an array of different ecosystems, but it has led to the recreation of otherwise unnecessary pathogens. In 2005, for example, Spanish flu was recreated in a New York laboratory, and a few years later Beijing researchers succeeded in replicating the genetic signature of the subspecies of *Y. pestis* responsible for starting the third plague pandemic.

Although the Cold War years of absolute mistrust may be over, bioresearch continues in the name of public health, and there is no doubt that much of it also benefits the advancement of germ warfare. Furthermore the break up of the **USSR** in 1991 and subsequent disaffection of Soviet scientists added a new dimension to the dissemination of military biotechnology.

The human species has helped numerous types of bacteria and virus to adapt and evolve much faster than would have naturally occurred without our intervention. By researching them and releasing them *(inadvertently or otherwise)* into the environment, humans ultimately encourage the spread of entirely new pathogens. Even if hazardous experimental strains are destroyed, *(as English biologist **'Rupert Sheldrake's** theory of morphic resonance has shown)*, the habitual relearning of microbial existence makes it more likely that an identical serotype' could re-emerge under natural conditions elsewhere in the world.

ix

(A natural conclusion)

Whilst there remains the possibility of numerous different natural disasters to befall mankind, it is highly unlikely that human extinction will occur in one fail swoop. Yet any one in a number of potential natural disasters could bring chaos to the modern world and send civilisation spiralling into oblivion. Whether it be celestial *(such as a coronal mass ejection or an asteroid/comet strike)*, geological *(such as a supervolcanic eruption, or megatsunami)* or even biospheric in nature *(such as ocean anoxia or a deadly pandemic)*, the effects of any of these scenarios could prove decisive and devastating to human civilisation. Indeed a large enough natural disaster would inevitably induce various further threats to our continued existence from mankind itself.

Should modern civilisation begin to crumble under the stress of an apocalyptic natural event *(whatever it may be)*, every community, no matter how distant, will be affected by its demise. A sudden physical disaster *(such as a devastating asteroid impact)* could, of course, result in almost instantaneous extinction for humans and many other species of life, however the probability of such an event happening in the near future is minimal. Unless the human world is instantly pulverised, modern civilisation will more likely collapse into general anarchy over a matter of weeks or months should, for example, a biospheric disaster *(such as ocean anoxia)* cause a more gradual extinction event. Under such circumstances, the first symptom of mankind's impending downfall would be a 'global economic meltdown'. As power networks start to fail and food supplies dwindle, social unrest would spread rapidly, with starving populations resorting to primitive instincts simply to survive. With national identity becoming a meaningless concept to the masses, even the strongest societies would become unstable, ultimately leading to internal power struggles and international war *(with any number of weapons of mass destruction at our disposal)*.

Although such an abhorrent scenario following a global natural disaster is highly probable, the reign of humanity will, more conceivably, come to an end directly as a result of our own doing. Indeed, rather than our downfall resulting from a completely unrelated natural disaster, the human race is far more likely to contribute to its own demise in a much wider sense. Anthropogenic climate change, irreversible pollution of the environment, and our unfettered exploitation of the Earth's natural resources by an overpopulated human species are by far the largest challenges facing our continued survival today.

Part 3

Human Malevolence

"The Earth does not belong to us; we belong to the Earth. This we know. All things are connected like the blood which unites one family. Whatever befalls the Earth befalls the sons and daughters of the Earth. We did not weave the web of life; we are merely a strand in it. Whatever we do to the web, we do to ourselves."

~ **Chief Seattle,** Suguamish Tribe *(1854)*

i.

***(Human interference:** to the detriment of life)*

The number of different living species on Earth today accounts for less than 0.1% of the total number of species that have ever existed on the planet. Yet our own species evolved at a time when life had become more diverse than it had ever been. Indeed it is estimated that there are currently almost 9 million separate species living today, even though life on Earth has endured five 'mass extinction' events and numerous other major extinction pulses during our planet's long history. Resulting in the loss of at least 50% of all genera, prehistoric mass extinctions were catastrophic for virtually all the terrestrial and aquatic ecosystems of the time. However by opening up new niches for surviving species, the most recent mass extinction events *(205 million and 65 million years ago)* ultimately led to an increase in diversity in the longer term as life adapted and further evolved to survive.

Yet the proliferation of *Homo sapiens* across the continents over the past 100,000 years or so has had an unprecedented global impact on the natural world, and today life faces an entirely new threat from mankind. Numerous 'higher' species of flora and fauna are suffering as a direct result of human activity, and a growing number are becoming endangered every year. Indeed with the populations of many species being decimated, some have already reached a point at which they are unlikely to ever recover, leading to the inevitable collapse of delicately balanced ecosystems. Moreover the current extinction rate is many times greater than it was before our own species first emerged, and it is highly likely that another, 'sixth', mass extinction is already underway. By the end of the present century the diversity of life that we currently enjoy on the planet will almost certainly have diminished considerably, with the rich variety of ecosystems of today being replaced by vast homogenised biomes.

To understand how human beings can have such a huge impact on the natural world, is to understand just how successful the intellectual evolution of our species has proven to be. In terms of survival, the advantage intelligence has given us in competition with other species is phenomenal. It has allowed us to exploit nature in ways that lie far beyond the comprehension and capabilities of any other life form, and has ultimately enabled the human population to swell to over 8 billion people. However the primitive emotions that existed long before the onset of 'behavioural modernity' still persist within the human mindset, putting the living world at the mercy of a 'uniquely human' greed that is empowered by a basic intellect. Common desires such as the pursuit of personal wealth, power and status have led to a wholesale disregard for other life *(particularly when the consequences aren't immediately obvious)* placing the natural world under enormous stress.

The first ‘anatomically modern humans’ evolved in Southern Africa some 195,000 years ago, and began migrating from the continent about 70,000 years later ~ initially reaching the Near East before spreading throughout Eurasia, By around 35,000 years ago modern humans extended throughout Europe, usurping their ancestral cousins, the Neanderthals who had been the dominant hominid here for some 200,000 years. Unable to compete with modern humans and adapt like they could to the colossal climatic changes that were afoot, *Homo sapiens neanderthalensis* would die out in another 7,000 years, leaving *Homo sapiens sapiens* as the only remaining hominine species on Earth. Over the following millennia our direct ancestors began to irrevocably change the face of the land having demonstrated symbolic thought and cultural creativity during what has been termed the ***‘Upper Palaeolithic Revolution’***.

By this time our prehistoric ancestors had started to spread across the globe, reaching Australasia around 40,000 years ago, and eventually the Americas where their impact on native wildlife was enormous. It is likely that small numbers of nomadic humans first reached the Americas sometime before 35,000 years ago via Beringia ~ a wide area of grassland steppe and tundra that once linked Siberia and Alaska. However less than a hundred miles east of this land bridge, passage was blocked by an inhospitable mountainous terrain where vast Alaskan glaciers prevented further migration southwards into the new continent. It was not until the ***‘Last Glacial Maximum’*** had started to subside that the human repopulation of Eastern Siberia and Western Alaska could resume, and by about 16,500 years ago small groups of Paleo-Indian hunter-gatherers had begun to venture inland. What had started as a small trickle of humanity had, by around 13,500 years ago, become a large influx of migrating people as the arrival of ***‘Clovis man’*** *(the ancestors of most native American peoples)* found an ice-free corridor through Canada to the northern plains. From here, human colonisation of the entire continent would occur within a matter of centuries. In the process mankind would unwittingly help to wipe out entire species of Pleistocene mammals, many of which had inhabited the continent for millions of years.

Whilst our prehistoric ancestors were not solely responsible for the mass extinction of megafauna in the Americas, their presence coincided with a series of catastrophic natural events that would put the survival of many species under serious threat. With the climate gradually warming, almost 10,000 years after the Last Glacial Maximum, had peaked, the widespread dispersal of the early Amerindians into North America continued almost unabated, However around 12,800 years ago, an intense cold period *(or stadial)* known as the ***‘Younger Dryas’*** interrupted the warming trend. Reaching its peak within a matter of decades, the stadial would last for over a millennia and have a profound effect on wildlife in the northern hemisphere. The most likely hypothesis for the appearance of the Younger Dryas proposes that a series of air bursts or impacts from a passing comet struck the continent shortly before its onset. Besides the likely cooling effect of dust particles in the atmosphere ‘dimming’ the sunlight for years, the initial energy from the blasts contributed to the collapse of the North American ice sheets which were already weakened by warming conditions. In turn, this released enough freshwater to disrupt thermohaline circulation of the North Atlantic, causing temperatures in the northern hemisphere to plummet.

This marked *(but geologically brief)* drop in temperature had several devastating repercussions for American wildlife. Most affected were the large Pleistocene mammals which had adapted and evolved to warmer climes. The ice had been in retreat for several millennia, but the sudden return to glacial conditions happened too rapidly for many large mammals to adapt. Animals that had undergone northern migration or evolved less hair/fur during the prolonged period of deglaciation were immediately disadvantaged, whilst the sudden onset of cold, dry winters killed swathes of vegetation and, in turn, the animals that depended on it.

But the Younger Dryas had another, less direct, consequence for the American wilderness. Although Beringia had been gradually shrinking for several thousand years, the stadial maintained a winter land bridge across the Bearing Straits. For centuries humans continued to enter Alaska this way, their passage into the Americas now no longer hindered by the foreboding ice sheets of the past. With large bands of hunter-gatherers already established in the continent, now an unprecedented wave of humanity added a new dimension to the ecological turmoil afoot.

The first American immigrants were general foragers, but as 'tribes' migrated southwards they increasingly turned to hunting big game ~ a plentiful and proteinaceous food source in harsh conditions. Continuing to spread throughout the continent, this powerful new predator entered Central and South America, systematically wiping out populations of big game on the way. Indeed the new human hunters pushed the already weakened populations of many species towards complete collapse. The desperate attempt for many indigenous mammals to survive, however, was dealt a final blow by nature. As the ice retreated and temperatures once more began to rise around 11,500 years ago, much of the continent had to endure a succession of sporadic but intense El Niño events *(not to mention a catastrophic flood in the north).* By the start of the Holocene epoch, America's megafauna had all but vanished.

Human migration to the Americas ultimately contributed to wiping out around two-thirds of all species of megafauna in North America. These unfortunate animals did not have the advantage of the large African game which had hundreds of thousands of years to adapt to human evolution in its infancy. Unable to recognise their human hunters as predators, a whole multitude of animals *(including the mastadons, ground sloths, giant beavers, camelops and several species of mammoth)*. were exterminated. With their prey in short supply, other top predators *(such as the sabre-toothed cats, cave lions and dire wolves)* also died out.

Whilst it's true that much of the American megafauna would have faced extinction anyway with the drastic environmental changes going on at this time, it is highly unlikely that all would have perished without the complicity of man. The mammoths, for example, had dominated the grasslands and open woodlands across the continent for some five million years prior to the appearance of *Homo sapiens* ~ surviving the onslaught of many earlier glacial periods, yet the last glacial peak was no harsher. Indeed archaeological evidence of spear heads and other manmade tools found amongst the cut bones of mammoths and other large mammals is widespread, indicating that hunting the indigenous megafauna was common practice ~ until, that is, they were hunted to extinction. It is interesting to note that almost all of the large American fauna which survives today is descended from Asian species' that evolved alongside their early human predators.

Over the course of 50,000 years or so, human expansion across the globe led to the disappearance of many hundreds of large animal species. Indeed early modern humans were, in part, responsible for creating an extinction spike that, in North America alone, claimed around 35 animal genera. Yet the annihilation of megafauna in the Americas during the Late Pleistocene was little more than a 'blip' at the start of an ongoing major extinction event which has become known as the ***'Holocene extinction'***. With human numbers and ever more proficient hunting techniques exacerbating the situation, the danger that our species posed *(and continues to pose)* to wildlife has only increased over time.

Today the situation is far more serious. Then the casualties were mostly large game, now however nearly every order of plant and animal life contains at least one species that is endangered. It has been postulated that, by 2010, up to a third of the world's wildlife had been lost over the preceding 40 years, with approximately 1% of known species becoming extinct every year. Whilst forests and other areas of natural vegetation are being cleared at an alarming rate, animal diversity is also shrinking fast, During the 20th century the number of terrestrial species fell by around 25%, marine species by some 29%, and birds by up to 30%. It is estimated that up to two million species became extinct over the 20th century and, by the start of the current century, around 55,000 plant and animal species were being lost annually. This equates to an extinction rate of 150 species every day, with some 30% of all living species likely to have gone by 2050. Indeed the rate at which modern flora and fauna are disappearing is currently in excess of a thousand times the 'background levels' that are seen in the fossil record, with the extinction rate continuing to rise.

With thousands of different species being lost every year, the lesser well-being of particular orders of animal within certain classes *(including the anthozoans, amphibians and insects)* reflects the deteriorating environmental conditions globally. In fact there are numerous species with low tolerance to discrete changes within their local environment, making them 'ideal indicators' of the living planet's wider state of health. Acting like the proverbial *'canary in a coal mine'* their continued survival is critical to the welfare of countless other species *(including our own)*, yet it ultimately depends on human decision.

Generally living in shallow tropical waters, ***'corals'*** are one good example ~ providing an important habitat for over 4000 different species of fish around the world. Despite being largely surrounded by nutrient-poor waters, the reefs that they build create the most diverse and productive of all ecosystems, and are often referred to as the *'rainforests of the oceans'*. Yet these fragile oases are also recognised as being highly sensitive to changes in the marine environment *(such as in temperature, acidity and salinity)* and most have severely degraded over recent decades.

The decline of coral reefs has been due to a number of *(largely human)* causes. Many reefs have been ravaged by destructive fishing techniques ~ such as the use of explosives for 'blast fishing' and chemicals for 'cyanide fishing', as well as unregulated trawling. Due to their proximity to the shoreline, some reefs have been suffocated by silt that has accumulated as a result of irresponsible land-based projects, *(including the building of dams and canals)*. Agricultural run-off, industrial effluent and other pollutants are also responsible as is, of course, climate change. Indeed the gradual warming of the world's oceans is synonymous with an increasing acidity of the seas, As ever greater quantities of atmospheric carbon dioxide are absorbed, so more carbonates are removed from the waters that are essential for calcifying organisms such as corals, molluscs and sea urchins. This is a major cause of what is perhaps the starkest feature of coral decline ~ 'coral bleaching'; where once dynamic ecosystems have been turned into silent white graveyards.

Almost a third of all the world's coral reefs are situated off Southeast Asia, where they have had to endure human interference for many centuries. Around 80% of the surviving reefs here are endangered, with losses becoming far more acute in recent decades. When local fisheries in the region ran out of stocks in the 1990's, many turned to coral fishing, and a wide variety of tropical fish continues to be poached today *(mostly as live catches for restaurants throughout the continent)*. Yet whenever large predators are removed from complex ecosystems such as coral reefs, the consequences are many. One recurring pattern from reefs that have been overfished, is a decline in predatory fish invariably leading to an increase in the numbers of molluscs and crustaceans such as scallops, lobsters, shrimp and prawns. This new abundance of seafood attracts larger fleets that exploit the area again, this time for shellfish. When their numbers are also wiped out, the reefs are often exposed to infestations of jellyfish or unwelcome incursions of algae, plankton and worms. This inevitably leads to a sharp decline in water quality, further degrading what remains of the reefs.

But these are not the only threats to coral reefs. When the impact of human interference is combined with a natural disaster it can prove utterly devastating. The exceptionally strong El Niño event of 1997-8, for example, irreversibly destroyed about 16% of the world's reefs. As the rate of global warming increases, so too does the intensity and frequency of El Niño events which only serves to raise the stress on aquatic ecosystems, Between the 1970's and the turn of the 21st century, coral reefs and mangrove forests had already declined by around 40%, and it is highly probable that all of the reefs currently existing off South East Asia *(which contain approximately three-quarters of the world's coral species)* will disappear before the end of the century,

When you consider that around a quarter of all known marine species depend on coral at some stage in their development, then the sheer scale of the disaster afoot becomes apparent. Indeed the demise of coral reefs is bad news for human beings too! With an economic value estimated to be around $180 billion a year, the world's remaining reefs play an integral role in sustaining the human population. Were they to be wiped out completely, fish stocks would plummet leading to widespread human starvation and even the potential collapse of world economies, Yet there is an entire class of vertebrates that is suffering an even greater loss than coral and its myriad of dependant species. Despite having been in existence for over 360 million years, ***'amphibians'*** are under the greatest risk of extinction through human activity. They have endured four of the five largest mass extinction events in the planet's living history, yet today almost all populations of frogs, salamanders and caecilians are declining, with over a third of the 10,000 or so amphibian species believed to be immediately threatened.

Were their populations to be completely wiped out, the consequences of their loss would be profound. Most extant species of amphibia are carnivorous and collectively consume invertebrates in their billions. Indeed they are essential to many food chains both as predator and prey. However in purely human terms, the importance of amphibians for the well-being of our own species is immense. Besides keeping many insect 'pest' populations from exploding, various species of frog, toad and newt have important pharmaceutical value. Their skin secretions, for example, can be used in the effective treatment of an array of human diseases. Yet the moribund state of amphibian populations around the world is exacerbated by numerous other human activities. Climate change *(for which they are sensitive indicators)*, habitat loss and pollution are all contributory factors in their decline. Furthermore, over a billion frogs are killed every year just for human consumption, and there is a huge illegal trade in numerous amphibian species as culinary delicacies. Perhaps the single greatest threat to their survival however comes from the fungal disease, *'chytridiomycosis'* which can sweep through some amphibian populations with a 100% mortality rate. Originally confined to southern Africa, the disease has now been spread globally as a result of the unscrupulous human trade in amphibians.

Whilst not as directly threatened as amphibians, there is another class of animal that plays a crucial role in the continued health of the biosphere. ***'Insects'*** however are not typically regarded when considering the plight of endangered species. Nonetheless, well over 100,000 species of insect have been lost over the past century, Generally speaking, they are regarded as pests that can actually benefit from climate change and pollution, yet this is not the case. There are over 6 million different types of insect *(accounting for more than half of all animal species)* but only a minority are actually responsible for damaging crops or transmitting disease. The ecological benefits of insects however are enormous. Not only is their existence vital to the food web, but they account for the most diverse class of pollinators, without which many flowering plants simply could not survive. Furthermore it is 'insectivorous' insects that, paradoxically, provide the most efficient form of pest control, keeping many harmful or damaging insect populations in check. Indeed nearly all terrestrial ecosystems can be seriously imbalanced by both the explosion and collapse of insect populations.

Yet many insect orders are under threat, and their disappearance could have untold repercussions for the continued existence of a great many species of plant and animal life. Dragonflies and damselflies, for example, are important predators, feeding on mosquitoes, flies, ants and wasps, however some species are in rapid decline. Because they lead a semi-aquatic existence, these insects are highly sensitive to changes in water quality and temperature, and *(like the corals and amphibians)* are good indicators of the rate of environmental decline.

Whilst the declining health of many dragonfly and damselfly populations reflects the degradation of local forest and freshwater systems, the insects most directly important to humans are bees ~ the continued survival of which is critical to that of our own. Bees are responsible for pollinating a great majority of the hundred or so crop species that account for 90% of the world's harvested food supply. Indeed they effectively provide around a third of all nutrition consumed by a burgeoning human population, yet they are largely treated with irreverence by people whose livelihoods do not directly depend on them.

Bees however share a mutual dependency with many species of plant, ensuring genetic diversity and cross-pollination in return for vital supplies of pollen and nectar to feed their young and survive the winter. However the final decades of the last century saw a rapid decline in 'pollinator' insects ~ which was particularly noticeable amongst many of the roughly 20,000 known species of bee. Agricultural chemicals, atmospheric pollutants and the inadvertent spread of disease between colonies through trade have all contributed to their decline. Moreover colonies *(both domesticated and wild)* that exist near urban areas are exposed even higher concentrations of pollution, with often serious consequences. One such pollutant, diesel fumes for example, contain nanoparticles that can effect the neurological capabilities of honeybees, drastically affecting their ability to navigate.

Another major factor in their decline is the loss of plant biodiversity resulting from modern farming techniques, and the creation of vast areas of plant monoculture. When the populations of 'non specialised' bee species are forced to consume the pollen from a narrow range of plants, their immune systems are compromised and whole colonies can readily fall victim to disease. Indeed when you factor in decades of pesticide misuse it is clear to see why many local populations of feral bees and other pollinating insects around the world are vulnerable to collapse.

Furthermore, besides having to cope any one or more of these threats, bee populations *(like those of so many other species)* are not immune to effects of anthropogenic climate change. The current warming trend is so rapid, that many animals and plants are unable to adapt fast enough. Indeed it threatens all species of bumblebee and honeybee *(including the **'Western honeybee'**)* whose role in pollination is vital to the food web. Were their populations to collapse completely, the loss of these important pollinators would be catastrophic for a myriad of crops ~ most likely leading to mass human starvation within a matter of months.

The present rapid decline in wildlife populations around the world is primarily caused by several major factors, all of which can be directly attributed to human activity. Habitat loss, pollution and disease *(to name but three)* are, for example, major killers in the natural world that often result from largely uncontrolled human practices. Throughout the 20th century, our wholesale abuse of the environment and systematic destruction of many ecosystems led to the extinction of hundreds of thousands of individual species. Even today, with millions of animal and plant species still yet to be recognised, many are immediately added to the 'endangered list' as soon as they are discovered. Moreover with the human population having grown by over 4 billion people in the space of just 50 years, the continued survival of many wildlife species is under greater threat than ever.

As human numbers rise, the natural world is put under ever more stress, and by continuing to exploit it as we do, we invariably put our own species' long-term survival at risk. Not only do we rely on exhaustible natural resources *(such as fish for food, timber for building, and fibre for clothing)* but, by exploiting the biophysical environment, we have destroyed the integrity of countless ecosystems and irrevocably changed the living planet. So profound are the effects of human activity that we actually jeopardise many vital 'support and regulating' systems that have served the biosphere for millions of years. Indeed the purification of air and water, the recycling of nutrients, and even the climacteric acts of pollination and seed dispersal are all compromised by human activity.

Over the past century, ceaseless agricultural and urban expansion destroyed the natural habitats of thousands of plant and animal species, Furthermore, with a global population now in excess of 8 billion people, ever more land and water is being utilised to support human life. Indeed our consumption of food and water actually doubled between the 1960's and the start of the 21st century. Yet despite the fact that 'key habitats' are now disappearing at an alarming rate, over-harvesting *(and over-consumption in the developed world)* continues, with our own species ultimately threatening to exploit much of the planet's natural resources to exhaustion.

The ability of human beings to adapt to the environment is unique in the animal world, allowing our species not just to survive but actually prosper in a wide range of climatic conditions. As a result human settlements occur on almost every sizeable landmass on the planet, and when wildlife populations face direct competition from humans for food or living space, there can only be one outcome, with the result often proving catastrophic for the native species concerned. Yet ever since our Palaeolithic ancestors began to exploit the natural world around them thousands of years ago, we have continued to drive wild species from their homes, forcing many remaining populations into ever-shrinking sanctuaries. Moreover, whilst most 'native' top predators in any given environment die out when their food source is no longer available, the same is not true of ourselves. The most successful of all hunters, humans are efficient *'switching predators'*, i.e.; our species is able to adapt to survive on whatever prey is readily available. Unfortunately we have become too efficient at hunting, killing many animal species faster than they are able reproduce.

Our continued destruction of natural habitats pushes numerous species towards extinction, with none more at risk than the myriad of specialised plants and animals that inhabit the world's tropical rainforests. Here, there are countless indigenous species whose entire population may span no more than a few square miles, and many have already been wiped out. Yet every species, no matter how narrow its influence, plays a unique part in the *'web of life'* that encompasses us all. Just as no species can exist on its own, so every form of life on the planet is supported by, and supports other living species. Alas, human activity can do irreparable damage to the biodiversity of an ecosystem in all sorts of ways; extinguishing so many species as to put our own existence at risk. In biological hotspots such as New Zealand, Hawaii and South America for example, the extinction of many native bird species has, in turn, led to the slow demise of bird-pollinating plants.

A more direct consequence of human activity is deforestation. Not only can it have a huge impact on fragile local ecosystems, but its effects are increasingly felt much further afield than the immediate environment. Indeed the clearing of natural vegetation on a large scale effectively lowers the water table, often causing the desertification of previously fertile land. However there is no indication that urban and agricultural advance is likely to slow without a major catastrophe to curtail it, and the industrial capacity of humans to destroy the very foundation of the living environment is already having far reaching effects. In the increasingly impoverished ecosystems within some developing nations, for example, massive deforestation threatens all forms of livelihood. With droughts becoming increasingly common, soils have degraded quicker - effecting both natural forest and agricultural land. The loss of essential crops and livestock, as well as a crash in the number of animals traditionally hunted for food, presented new challenges to feed the swelling human population. This has in turn put a greater demand on seafood, leading to widespread overfishing, where a depletion of 'higher predators' has ultimately led to the infestation of jellyfish in once productive local waters.

Throughout much of the world, trees are being felled faster than they are being replaced, with the loss of tropical rainforests particularly germane. Each year, virgin rainforest with a combined area roughly the size of Greece is cleared, usually to make way for plantations, livestock pastures or heavy industry such as logging and mining. Amazonia *(the world's largest expanse of rainforest)* had, by 2010, lost around 40% of its canopy since the start industrial era, whilst the major Asian and African forests in countries such as Thailand, Indonesia, Nigeria and Tanzania had been reduced by over 80%. Some 90% of the rainforests that once covered the Philippine archipelago had also been lost, whilst the forests of Madagascar had declined by over 95%, For every square mile of tropical forest that is cleared, hundreds *(possibly thousands)* of species can be lost forever - most of which will have never been documented by science. Indeed it has been said that, in the search for natural medicines there is a race between science and extinction. Even in purely economic terms, the loss of rainforest globally is estimated to ultimately cost around $5 trillion annually.

At the turn of the 21st century the world's rainforests were releasing in excess of 20 billion tons of water vapour into the atmosphere every day. However as more and more trees are cleared, so less water is evaporated from branches and leaves back into the atmosphere, inevitably causing local rainfall to decline. Throughout the tropics, deforestation and climate change have conspired to transform once lush areas of forest into dry scrubland - a pattern that is likely to have catastrophic consequences for the world's climate. Alas the rain that does fall in tropical regions which have lost forest canopy can do more damage than good. Without suitable vegetation to absorb the deluge from a storm, there is increased 'runoff', leading to a higher risk of flash flooding. This in turn can cause a loss of topsoil, greater erosion and further desertification of the land. Moreover with a drier climate comes an increased likelihood that large-scale fires will further degrade remaining areas of virgin forest.

Forest fires can unlock vast amounts of carbon that had been stored in the wood and soil for many millennia, releasing it into the atmosphere as carbon dioxide. A major green house gas, the CO_2 released from forest fires further adds to the gradual rise in global temperatures, so perpetuating a vicious cycle. In 2005, for example, parts of the Amazon Basin experienced the worst drought for more than a century. This was followed five years later with an even more severe drought that affected over a million square miles of forest. Yet the shrinking Amazon is not only becoming more susceptible to drought but it is becoming increasingly less resistant to it, with widening areas of savannah and desert threatening to push the rainforest towards the 'tipping point' of irreversible decline. In a typical year the Amazon Rainforest was believed to absorb approximately 1½ billion tons of CO_2, yet the droughts of 2005 and 2010 had the reverse effect, releasing a combined 13 billion tons of CO_2 back into the atmosphere. With rapid deforestation, severe drought and devastating wildfires all taking their toll on the Amazon during the 2010's, it is believed that, by 2021, this once mighty rainforest had possibly passed the point of irreversible collapse. Indeed all of the world's forests are becoming ever less efficient at extracting CO_2 and other pollutants from the air, gradually destabilising the planet's fragile biosphere.

Pollution is another consequence of human activity that threatens the natural environment in every continent, and our species is responsible for polluting the Earth in a huge variety of ways. The quality of soil and water in many regions of the world, for example, has been reduced by contamination from urban and agricultural runoff, with effluent from untreated sewage, fertilisers, and herbicides doing untold damage to various natural habitats. Industrial waste too can be highly dangerous, with heavy metals and chlorinated hydrocarbons readily poisoning the environment. The long-term effects of *'persistent organic pollutants'* created in the manufacture and use of pesticides, solvents and pharmaceuticals can be particularly damaging, whilst air pollution from the expulsion of carbon monoxide, sulphur dioxide, and nitrogen oxides can be far-reaching. It has caused acid rain *(leading to the degradation of many northern forests)* and created photochemical pollutants such as smog and low-level ozone that is detrimental to the health of many plant and animal species. Then there's the radioactive contamination of land, sea and air from nuclear waste and warfare technology. However the single greatest threat to wildlife from anthropogenic pollution takes the form of excessive carbon dioxide emissions *(largely through the combustion of fossil fuels)*, contributing to a steady rise in the mean global temperature.

The Earth's climate has warmed and cooled many millions of times throughout its long history, fluctuating between 'greenhouse' and 'icehouse' conditions. Even when ice ages prevail, the cyclical pattern continues with cold, dry glacial periods being punctuated by warmer and wetter interglacials. In all cases concentrations of atmospheric CO_2 are greater when the mean global temperature rises. Yet warming of the past has occurred as a result of natural phenomena such as variations in solar output and the Earth's orbit, as well as terrestrial forces such as volcanism and plate tectonics, However *(apart from the aftermath of the occasional major asteroid strike)* climate change has never occurred as rapidly as it is today, and the planet is currently experiencing its highest mean temperatures for some 120,000 years.

This present rise is happening too abruptly for numerous species to adapt, with many migrating animals having to travel further north or south each year in order to find an ideal habitat to exist. Indeed a myriad of animal and plant species *(from butterflies and birds, to algae and pine seedlings)* are struggling to survive as subtropical conditions increasingly prevail and the world's temperate zones creep inexorably towards higher latitudes. Mammals and birds that specialise in the coldest climatic extremes feel the squeeze most of all. Unfortunately for many Arctic and Antarctic species, such as polar bears, narwhals and emperor penguins, the warming climate has caused massive habitat loss and a drastic decline in food availability. Yet for these animals there is nowhere else to go.

Just as climate change can have a wholly disruptive effect on many animals by shifting or reducing the size of their habitats, so direct human exploitation of the natural environment can drastically alter the face of the land, destroying the homes of many indigenous species. Nowhere is this islandisation of the wilderness, more apparent than in the tropics, where logging, road building and agricultural expansion have severed most rainforests beyond repair. In places where small pockets of pristine rainforest have been left as natural reserves, re-growth of native vegetation at the boundary is quickly stifled. Indeed most 'islands' of forest suffer a slow encroachment of 'weedy' species that become established in cleared areas around the edge, causing these small oases to gradually decay. Here, many native species become isolated, with plants unable to cross-pollinate and animals not able to reach suitable mates - dooming local populations to certain extinction.

This problem is particularly pronounced in Africa, where human populations are encroaching on vast swathes of wilderness. In Kenya's ***'Masai Mara National Reserve',*** for example, the numbers of large grazing animals such as giraffes, impala and topi declined by around 50% over the course of the last 20 years of the 20th century, Invariably the populations of large predators also declined, as their food source diminished, bringing many large carnivores into contact with human settlements which had begun to encroach upon the peripheries of the reserve. The rapid growth of Masai settlements in the vicinity also served to effectively cut off many migration routes between the park and the neighbouring Serengeti. This has had a profound effect on the African megafauna with the total population of bush and forest elephants, for example, falling tenfold over the last century. Like their Asian cousins, the numbers of African elephants are plummeting with many remaining populations living in 'closed reserves', often unable to reach their winter feeding grounds or spring breeding areas. Indeed, when forced to inhabit overcrowded areas too small to sustain them, Africa's remaining wild elephants can cause huge environmental damage. Alas the combined area of land set aside as wildlife reserve in Africa is just 1.7% of the total landmass, with most parks and reserves too small and isolated for any long term sustainability.

Of the remaining ecosystems in the world that are still relatively unspoiled by human activity, none are immune from the potential spread of invasive species. A by-product of modern globalisation, the movement of non-indigenous plants and animals around the world is almost unavoidable. Indeed countless 'alien species' have been intentionally introduced to new areas for financial, agricultural or even environmental benefit. However the potential damage an introduced species may bring to its 'host ecosystem' can be subtle and may not be evident for several generations.

With human beings acting as primary vectors, the spread of non-native species throughout the world continues at pace, as countless different species are transported daily for a huge variety of purposes, legal or otherwise. There is, for example, an illicit trade in exotic animals and plants of almost every order and, with millions sold as pets and curios every year, this industry alone is worth billions of dollars. Yet whether imported for financial gain, a perceived ecological benefit, or even on aesthetic grounds, the consequences of introducing new species to 'unnatural' wilderness can be devastating for local ecosystems. It can threaten biological diversity, with introduced species sometimes outcompeting native ones to become established or even dominant.

Most invasive species are, by nature, hardier than their native counterparts, allowing them to fill existing niches or create new ones within the local ecosystem. With an ability to adapt to new environmental conditions, many invasive species carry traits such as rapid growth or faster reproductive cycles that give them a huge advantage. They may be more tolerant to disease or, in some cases, actually carry infections for which native competitors have no immunity. They may be similar enough to cause genetic pollution *(an unintentional 'hybridisation with local species)*, or be different enough to poison unsuspecting local predators. The ill-conceived introduction of European rabbits and cane toads to Australia, or of Asian mongoose and feral pigs to Hawaii. for example, are well documented cases which highlight the damage that introducing alien species can cause. Whatever the eventual outcome, when distant species manage to become established in foreign environments, they invariably do so to the detriment of various local species and the ecosystems they help to support.

It is recognised that biodiversity underpins the health of the living planet, but human beings have a long history of treating life with flagrant disregard. Plant and animal species are still largely treated as mere commodities, yet the continued loss of biodiversity will have an ever greater impact on human life. As a result of our interference with nature, not only is species distribution becoming increasingly homogenous, but genetic diversity itself is rapidly declining. In order to avoid a disaster of global proportions, there must be a significant shift in consumption patterns and a degree of education that is far beyond our present capabilities. Indeed, the urgency with which we need to react is highlighted by the fact that within a single human generation, the major concern of conservationists worldwide has gone from a relatively small number of highly threatened species to the collapse of entire ecosystems.

Originally set up in 1948, the ***'International Union for the Conservation of Nature' (IUCN)*** became the first multilateral organisation formed to combat ecological decline. In 1963 the first ***'IUCN Red List'*** was published, which evaluated the extinction risk to tens of thousands of different species, and attempted to rank them according to their conservation status. Reviewed at least once a decade, the Red List has highlighted an alarming decline in the health of many ecosystems, with the 2012 list, for example, showing almost a third of the some 64,000 species and subspecies assessed to be threatened with extinction in the short term.

With an index of seven main categories, the **IUCN** Red List provides the most comprehensive record we have concerning the health of life on Earth, but it is far from complete. Indeed two categories have been assigned to species that are either *'data deficient'* or *'not evaluated'*, meaning that their conservation status cannot be accurately determined.

At the top of the core list are species of '*least concern'*; those whose populations are suffering no apparent detrimental effect or, like humans, are actually thriving in the current climate. Animal species in this category include the 'common wood pigeon' and the 'house mouse'. Next come species that are '*near threatened';* i.e. those currently considered to be at lower risk and face no immediate threat, but are likely to do so in the future. Such animals include the 'European otter' and the 'plains zebra'. Despite their current 'low threat status', many of the thousands of species placed in this category are nonetheless conservation-dependent.

Those species considered to be actually *'threatened'* are subdivided in to three further categories; the criteria for which are based on the size of population, rate of decline, and the severity of known threats. The first of these categories, *'vulnerable'*, includes the 'polar bear' and the 'blacktip shark', both of which are believed to face a high risk of becoming extinct in the medium term. Next come *'endangered'* species such as the 'blue whale' and the 'Komodo dragon' which are considered to be at a very high risk of extinction in the near future. Lastly, species that are *'critically endangered'*; where the entire population has declined *(or is likely to decline)* by over 80% within three generations. Animals placed in this category include the 'Amur leopard' *(whose population, in 2021, numbered less than 100)* and the 'Javan rhinoceros' *(of which only 60 individuals remained in the wild by 2018)*.

Listed at the 'sharp' end of the Red List index, are animals and plants that are *'extinct in the wild'*; i.e. species where all known specimens survive only in captivity ~ such as the 'Seychelles giant tortoise' and the 'Socorro dove'. The final category includes species that have completely disappeared over the past five centuries. Animals that fall in this '*extinct*' category include the 'dodo' which was wiped out in 1662, and the 'thylacine' *(or 'Tasmanian wolf')* ~ the last of which died in captivity in 1936.

It is a sad fact that, within a human lifetime, countless species are likely to join the dodo and thylacine, as thousands of different animal and plant populations head inexorably towards total collapse. Other animals to have suffered recent extinctions include the 'Caspian tiger' in 1973 *(through human encroachment and hunting)*, the ‘golden toad’ in 1989 *(through habitat loss, climate change and disease)*, and the ‘West African black rhinoceros' in 2006 *(through poaching)*. Whilst the death of any species is tragic, two particularly shocking extinctions occurred recently in China. Declared functionally extinct, the last confirmed sighting of a ‘baiji’ *(or ‘Yangtze River dolphin’)* occurred in 2006. With its population having been decimated by illegal fishing, habitat loss and pollution, it sadly became the first cetacean to become extinct in recorded history. Like the baiji, the ‘Chinese paddlefish’ largely inhabited the Yangtze River and, until its complete demise in 2007 from overfishing, was the world’s largest species of freshwater fish.

Of course it is not just animals that are suffering. Over the past century, many thousands of endemic plant species from every continent have been lost forever. In 1933, for example, the much lamented ‘Cry Violet’ *Viola cryana* completely disappeared from the wilderness of northern France, although it survived in cultivation for a further twenty years. Other recent floral extinctions include the ‘Sri Lanka legume’ *Crudia zeylanica (from 1990)*, the ‘Colombian pradosia’ *Pradosia mutisii (1997)*, *Acacia kingiana* ~ a species of wattle indigenous to south-western Australia *(from 1999),* and the ‘St. Helena olive’ *Nesiota elliptica*; of which the last individual plant died in cultivation in 2003.

Yet the true number of animals and plants to have become extinct over the last hundred years is far larger than most people comprehend ~ possibly exceeding a million separate species. The uncomfortable fact is that almost every one of these extinctions resulted, either directly or indirectly, from human interference with the natural world.

As the power and efficiency of technology grew during the 20th century, so the expansion of human civilisation threatened the continued survival of increasing numbers of different species. Alas unfettered human intrigue and the urge to exploit the environment is still far greater than all of the world’s wildlife protection and conservation efforts combined. Indeed, in many parts of the world, the loss of a native species *(no matter how ecologically important or aesthetically prominent)* will often be of little concern to local people when they themselves have to endure a day to day struggle for life. Sadly whenever a species becomes extinct, the direct living experiences of people that once lived alongside it is also lost after just a few generations. It is the fate of extinct animals to be quickly forgotten from the psyche of the local human population, with many indigenous species effectively becoming regarded as creatures of myth. This sad loss of biodiversity continues unabated, and today we can experience a rich natural environment that later generations of human beings will never know.

Because so many species are under threat, only a very small percentage that are at risk of extinction will actually be added to the Red List. In fact many plant and animal species often reach the ‘tipping point’ before the threat to their existence is realised, or sometimes before they are even known to science. However, even those that are not overlooked, are often denied legal protection. In the United States, for example, animals and plants that are protected by the 1973 ***‘Endangered Species Act’*** account for less than 10% of the known number of species that are actually under threat in the country.

Paradoxically being placed on the Red List *(or any other list of threatened species)* can also have an adverse effect on the endangered animals it is designed to protect. It has been an uncomfortably common practice amongst farmers and landowners to cull an endangered animal species or destroy its habitats if its presence threatens commercial development, or prevents the expansion of prime land for agriculture or construction. Furthermore certain plants and animals become more desirable to collectors and poachers when their species are threatened with extinction. As their population falls, so their perceived commercial value increases, leading to their further decline. Yet endangered species can be invaluable to anything from the health of ecosystems to human medicine.

Despite the best efforts of numerous conservation movements throughout the world, wildlife continues to suffer at the hands of human beings. Whilst there are a plethora of non-governmental organisations dedicated to combating environmental destruction *(such as the **'World Wide Fund for Nature** [or **WWF** - 1961] and **'Conservation International'** [1987])*, human attempts to protect biodiversity are pretty insignificant when compared to the incalculable damage caused by our interference with nature. Even when you factor in the numerous international treaties designed to enforce wildlife conservation, human exploitation of the natural world far outweighs our collective desire to protect it. Although the 1973 ***'Convention on Trade in Endangered Species' (CITES)***, for example was important for bringing international accord on the morality of such practices, it alone could never halt a decline in the numbers of species that it was contrived to protect.

Perhaps the first concrete international efforts to curb the continuing loss of biodiversity were made in Rio de Janeiro, in 1992, at the ***'United Nations Conference on Environment and Development' (UNCED)*** ~ informally known as the ***'Earth Summit'***. Besides setting out principles designed to encourage sustainable development in all member countries *(known as the 'Rio Declaration on Environment and Development')*, it opened for signature two legally-binding multilateral treaties; namely the ***'Convention on Biological Diversity' (CBD)*** and the ***'Framework Convention on 'Climate Change' (FCCC)***. Despite being ratified in almost 200 nations, most signatories failed miserably to meet their 2010 targets, with many proving incapable of even slowing the loss of biodiversity within their respective territories.

Revisited in 2012 as the ***'UN Conference on Sustainable Development'*** *(or **'Rio+20'**)*, this summit confirmed a bleak outlook for the planet's stuttering ecosystems. Furthermore a collective absence of leaders from several Western democracies reflected a lack of urgency, and reaffirmed the failure of many governments to prioritise important environmental issues. Unsurprisingly most signatories ultimately appeared unable or unwilling to reach agreed targets for curbing biodiversity loss. Yet with some 70% of known plants and around 40% of all vertebrate animals presently considered to be endangered. *(i.e. they face a high risk of extinction)* and, with only a little more than 10% of the planet's surface set aside for conservation *(where habitats are actually protected from exploitation)*, biodiversity will inevitably continue to fall and species after species will move down the Red List index towards total extinction.

Today we stand at the precipice of a sudden mass extinction event that is likely to impact almost every order of life on Earth. Indeed it is highly likely that over half of all species living today will either be critically endangered or extinct before the end of the 21st century. However, whilst a myriad of different plant and animal populations are on the verge of collapse, few endangered species actually gain credible publicity. Excepting large animals whose plight has been highlighted because of their general appeal *(such as the 'giant panda', 'mountain gorilla' and 'Siberian tiger')*, most species will become extinct with little awareness or public concern,

Hunted for centuries for its much-prized fur, the unfortunate plight of the giant panda made it the ideal candidate for high profile conservation, and in 1961 its distinct imagery was adopted as the logo for the **WWF**. Thanks to the global publicity generated, an inordinate amount of funds have been made available for panda conservation compared to that of other endangered species. Even so, by 2015 less than 1900 individuals remained in the mountainous wilds of central China.

Despite having national reserves set up in three central African states primarily for its conservation, the mountain gorilla has faired less well in recent decades. Inadequately protected by park guards, the mountain gorilla continues to endure widespread poaching and a diminishing habitat. Throughout the 1990's, for example, the region was hotbed of human conflict, with a vicious civil war in Rwanda, leading to genocide and the two ***'Congo wars'***. As a result, the creation of huge refugee camps pushed humanity ever deeper into the central African wilderness where once pristine forests now provided the vital fuel for hundreds of thousands of desperate people. By 2018 the mountain gorilla survived as two separate populations whose combined numbers totalled around 1000.

Hunted to near extinction, the world's largest cat species, the Siberian *(or Amur)* tiger, has also clung on to survival with around 500 tigers remaining outside of captivity as of 2015. However with under 200 breeding individuals left in the wild, the Siberian tiger has succumb to an unrecoverable decline in genetic diversity. Before the onset of the industrial age the subspecies enjoyed a significant and comparatively large contiguous population throughout Far East Asia. Now extinct in China and only found in north-east Russia, only two wild populations of Siberian tiger remain, and *(like those of the mountain gorilla)* are irrevocably separated from one another.

Of course bears, gorillas and tigers represent just a minute proportion of endangered mammals. Furthermore, mammals themselves represent just a small proportion of animals that are currently threatened, with equally magnificent creatures of other classes just as vulnerable to extinction. For example, thousands of different birds from all corners of the globe are also under threat, with more species every year becoming endangered as the integrity of the ecosystems they inhabit begin to crumble. Iconic birds as far removed from one another as vultures and penguins are likely to suffer a similar fate as a result of irresponsible human activity.

During the 1990's the number of 'slender-billed vultures' in India was in the millions, yet within a decade its total population had fallen to under 1000 individuals. Whilst hunting and intentional poisoning played its part, the collapse was largely caused by veterinary *'diclofenac'*; a non-steroidal anti-inflammatory drug that was regularly used on livestock at the turn of present century. Acting as a poison to most species of vulture, diclofenac causes kidney failure making the carcasses they feed on lethal to the birds. Although now banned throughout the subcontinent, widespread illicit use of the agent continues.

Meanwhile in the Antarctic, the 'Emperor Penguin' *(the largest of all penguin species)* is on the verge of a similar collapse in numbers. The retreating ice shelves *(along with industrial-scale fishing in the South Atlantic)* has had a profound effect on its population dynamics. Indeed penguins are highly sensitive to climate change, and colonies of Emperor Penguins will inevitably suffer, with numbers likely to decline by up to 95% over the course of the present century.

By the turn of the 21st century, human beings had caused unprecedented damage to the environment, with countless animal species, from the largest to the smallest, pushed towards extinction. Particularly worrying is the ongoing fall in zooplankton numbers in the world's most productive waters. Zooplankton form the basis of important marine food chains on which every class of aquatic animal *(from crustacean and fish, to seabird and mammal)* ultimately depends. However their numbers have dropped by almost 75% over the past 50 years, leading to a disastrous fall in biodiversity throughout much of the world's oceans. The 'knock-on effect' of this *(combined with overfishing, pollution and disease)* has left many marine ecosystems on the verge of total collapse. Over the same time frame, for example, over 85% of the world's 'oyster reefs' were lost and, with many surviving reefs now classified as functionally extinct, they are currently be the most severely impacted of all marine habitats.

With such a wide variety of animals heading towards extinction, it is only a matter of time before food webs become severely disrupted and major ecosystems start to collapse. Some endangered animals are what's known as *'keystone species';* i.e. their continued survival is critical in maintaining stability within an ecosystem. The complete disappearance of a keystone species can have serious repercussions for its native environment ~ threatening the survival of the many other organisms that depend on it. Keystone species may simply be large grazing herbivores that prevent certain plants from becoming too invasive, or they may be carnivores whose prey would otherwise destroy species of flora whose existence is vital for the survival of other native species.

There are numerous examples of keystone species that are either vulnerable or endangered. Amongst the best known are the 'Asian elephant', the 'cassowary', and the 'Mexican prairie dog'. Another is the 'sea otter' whose population was decimated by the fur trade over the course of more than two centuries. The loss of sea otters from many parts of the North Pacific coastline profoundly altered the marine environment and irrevocably damaged countless aquatic ecosystems. Sea otters feed on a variety of marine invertebrates, including certain bottom-dwelling sea urchins whose numbers exploded following the otters' demise. Consuming almost any organic material in their path *(including the anchor stems of kelp)*, the dramatic rise in sea urchin populations wreaked havoc, turning once productive coastal waters barren. Left unchecked, large populations of sea urchins can destroy vast areas of kelp forest which provides the necessary shelter and nutrients for a whole host of marine species.

For every endangered 'keystone species' there are thousands of others whose eventual loss may not have such a direct impact on the environment, but that does not in any way diminish the importance of their existence. Indeed for many of the countless species that stand on the verge of extinction or have recently been lost, the ultimate consequences may yet to be felt by humans. The adverse effects on marine environments from the sharp decline in turtle numbers, for example, may not be immediately apparent but, having existed for over 215 million years, there is little doubt that their disappearance would have a profound effect on many aquatic ecosystems. Hunted for both their meat and shells, several million have been killed over the past few decades for everything from culinary delicacies and traditional medicines to souvenirs and even cosmetics. Moreover similar numbers have died as a result of pollution, with discarded plastic bags presenting a major hazard. The greatest number of casualties however have drowned after being inadvertently snared on hooks or caught in gill-nets and trawls by unscrupulous fishermen. With most species of turtle either endangered or critically endangered *(and declining rapidly)*, there is a fair chance that the order *Testudines* could disappear altogether over the next century. Yet a world without turtles will be much poorer for their absence.

Thanks to the huge over-capacity of the modern fishing industry, well over 80% of all edible fish are harvested above their rate of reproduction. Indeed the fish stocks in waters near large human populations have suffered enormously over the past century *(particularly those in seas off the first industrialised nations)*. Following the introduction of mechanised fishing vessels in the late 19th century, waters around the **UK**, for example, have been heavily over-fished. At its peak in the 1950's, over 3000 British trawlers were operating in the North Sea and they were, of course, not alone ~ with the various-sized fleets of several other European nations also fishing its waters. Since then, fish stocks here have dwindled by over 95%, with the stressed populations of halibut, haddock and plaice, for example, unlikely to ever recover.

Our blue planet is entering an accelerated phase of extinction, with numerous marine species fast disappearing from the oceans of the world. This is largely due to a combination of overfishing, pollution and climate change, the cumulative effect of which has brought about catastrophic changes to the Earth's oceans. Currently absorbing more $\mathbf{CO_2}$ than they did during the last major extinction event *(some 55 million years ago)*, the world's oceans have experienced a gradual warming over the past century. This alone has damaged a diverse array of marine ecosystems that exist in everything from coral reefs to Antarctic shallows. Meantime, widespread pollutants, such as plastic particles and agricultural fertilisers, not only pass readily up the food chain, poisoning a huge variety of different animal species, but have significantly contributed to an increase in toxic algal blooms and acidification of ocean waters. Moreover, with an ever-growing number of human mouths to feed, the world's oceans are being reaped on an industrial scale and, as a result, the populations of numerous fish species have plummeted over the past decades.

By the turn of the 21st century over 90 million tons of fish were being caught annually and, with the human population continuing to rise, it is unlikely that the problem of overfishing will be solved pragmatically. Indeed every marine species that is considered to have 'commercial value' is likely to be fished until its wild populations collapse. Large predator fish, such as swordfish and shark for example, have seen their numbers decline by over 90% since the middle of the 20th century, upsetting the balance of entire marine ecosystems.

Of all large predator fish, it is perhaps the depletion of Atlantic cod that is felt most profoundly. Whist fish stocks in general across the North Atlantic have fallen sharply since the 1980's, the consequences of overfishing were starkest around the ***'Grand Banks of Newfoundland'***. Caused by a plateauing continental shelf, the Grand Banks is a vast region of shallow water off the south-east coast of Newfoundland that happens to occur where the cold 'Labrador Current' meets the warm waters of the 'Gulf Stream'. The upwelling of nutrients here occurs on an unprecedented scale and, as a result, the Grand Banks were one of the richest fishing grounds on the planet with populations of Atlantic cod, haddock and capelin all once thriving.

In 1950's and 60's however, the introduction of enormous high-tech vessels equipped with sonar and massive trawl nets enabled the region to be swept indiscriminately. Not only was cod caught in vast numbers, but so too were numerous other species ~ often as an 'unwanted' by-catch. These included capelin, whiting and silver hake; all of which were important in sustaining the cod population. Following a partial collapse in the mid-1970's, in 1992 the Atlantic north-west cod fishery inevitably collapsed completely, with the population falling by over 99% in a single season. The resulting Canadian moratorium represented the largest industrial closure in Canadian history, with over 40,000 jobs effectively lost overnight. Caused by a gross mismanagement of the fisheries industry, the wiping-out of Atlantic cod stocks around the Grand Banks was, of course a huge ecological and economic disaster. Within seven years all Atlantic cod populations, including the 'Labrador', 'Iceland' and 'North Sea' stocks, had depleted beyond the point of any hope of recovery. Despite 'politically motivated' attempts to suppress information concerning the true state of Atlantic cod stocks, in 2000 it was finally listed as an endangered species.

Tuna, like cod, has been hunted by man for millennia but, with the introduction of large scale industrial fishing in the 1950's, wild populations are unlikely to survive beyond the next few decades. Today almost all of the ocean's tuna stocks are either overexploited or utterly depleted, with only numbers of skipjack tuna remaining comparatively healthy. Indeed, all three subspecies of bluefin tuna are under immediate threat of extinction, yet both Atlantic and southern bluefin tuna remain highly coveted as seafood throughout the world.

Hugely profitable, tuna are commercially caught in their millions using massive drawstring nets that are capable of devouring entire shoals. So lucrative is the market for tuna that, once caught, none are spared ~ with even juveniles kept to be fattened up and sold on to restaurants and fishmongers. In fact, there is such a voracious demand for tuna, particularly in Japan and the United States, that illegal catches amount to well over double the accepted quotas; with the fisheries of numerous countries regularly underreporting their catches. Yet by the mid-1990's, the population of bluefin tuna had already declined by 80% since the 1950's, and the species was declared critically endangered in 2009. Hunted to near extinction, bluefin tuna continues to suffer at the hands of unscrupulous commercial intrigue. At the start of the 21st century, the Japanese multinational ***'Mitsubishi Corporation'***, for example, actively embarked on a policy of increased fishing for southern bluefin, fully aware of its recent population collapse. Filling huge warehouses with frozen fish, Mitsubishi currently hold around 40% of the world market of bluefin tuna, knowing that the value of their stock will increase dramatically should it be declared 'extinct in the wild'.

With once 'commonly caught' fish *(such as cod and tuna)* seeing a sharp decline in recent decades, many fishing fleets have turned to catching deep water fish. However, because they inhabit the colder, darker regions around the seabed, most species of 'demersal' and 'benthic' fish have longer life cycles and are slower to mature than their 'pelagic' cousins. As a result populations of many such oceanic and deep water fish take longer to recover from overfishing, and various species of hake, skate and eel, for example, are now critically endangered ~ having seen their populations plummet by as much as 98% in little more than a decade. It is the commercial fishing of these and other deepwater fish that can result in the greatest physical damage to life in the world's oceans.

Dragging their massive weighted nets across the ocean floor, 'bottom-trawling' vessels can have an enormous ecological impact. Covering an area of several football pitches, the largest trawling nets can pass through 200,000 cubic feet of water every second. They can be hugely destructive, pulverising delicate marine ecosystems ~ not only destroying the nurseries that support many species of fish, but transforming the entire marine environment for hundreds of miles around. Indeed, the interminable use of bottom-trawlers in the modern fishing fleet has been likened to ploughing the same field seven times every year. However, even more disturbing than the indiscriminate nature of bottom-trawling *(amongst other methods of commercial fishing)*, is how wasteful the industry is. Every year over 100 million tons of unwanted fish and other marine species are taken from the oceans as a 'by-product' and thrown back dead or dying.

It is incredible to think that since 1988 all stocks of commercially fished species have fallen in every ocean of the world, but this profound decline was not universally accepted as fact for a further fourteen years. Indeed, unwilling to recognise the sheer scale of destruction that they cause, the world's fisheries still make billions of dollars annually from practices that are effectively decimating the remaining populations of numerous species of fish. Wholly unsustainable, the industry is slowly being strangled as it fishes itself out of existence. Yet, under the stresses of a growing human population, the world's ever-dwindling fish stocks have even greater repercussions for the very species they represent. Overfishing encourages natural selection to favour slow-growing smaller fish, diminishing the population's reproductive potential. Once the natural traits that helped the fish to become healthy and successful are eradicated from the species' gene pool, they are effectively lost forever ~ making the full recovery of depleted stocks unlikely to ever occur.

At the start of the 21st century, over 25 million tonnes of fish *(worth in excess of $28 billion)* were landed illegally every year. By 2010 over 80% of the world's fish stocks were considered to be suffering from over-exploitation, with illegal catches having a significant impact on the sustainability of targeted species. Yet **UN** regulations regarding *'illegal, unreported and unregulated'* fishing are virtually impossible to enforce. With stocks dwindling and the human appetite for fish becoming ever more voracious, trawling the seas with unconscionable intent can be a lucrative business. Often either flying 'flags of convenience' or totally unlicensed, most illegal trawls will ignore regulations completely and directly target prohibited species *(which are invariably the most profitable)*. However 'pirate fleets' not only threaten the total extinction of many species of fish, but have also had a huge impact on the populations of other marine animals. Hundreds of thousands of albatrosses and petrels, for example, are drowned every year trying to retrieve catches from long-line hooks strung out by poachers ~ a practice which ensnares sea turtles in equally high numbers.

Whilst it is a global problem, 'pirate fishing' is perhaps most prevalent in waters around the African continent and South-east Asia. Numbers of fish off the East African coast, for example, have declined at an alarming rate, with unregulated trawls responsible for up to a third of all catches. Here, a plethora of international trawlers have destroyed nesting areas and depleted the fish stocks so severely that local fishermen have seen their livelihoods disappear in a matter of years. The state of the waters off West Africa have faired no better, with many stocks here also on the brink of collapse. The 'rich' seas around Senegal, Guinea and Sierra Leone, for example, once teamed with fish but are now more commonly infested with jellyfish and other undesirable invertebrates.

Most of the world's seas, rivers and lakes, as well as every ocean is being fished to death ~ and not just through commercial venture *(sanctioned or otherwise)*. Indeed an estimated 1.4 billion fish are landed every year, either for personal consumption or simply as a recreational pastime. So deep-rooted is the human penchant for seafood that every species of large fish is at a considerable risk of extinction. By the start of the 21st century about a third of all stocks of edible fish were heading for certain collapse and, should the current rate of fishing continue, the oceans would be completely exhausted by 2050.

The problem that we face regarding the supply and demand of seafood is glaring, yet only short-term solutions have been readily sought. However, the idea of *'sustainable fish farming'* is an illusion. Indeed even more 'wild fish' are now caught to supply such aquacultures with fishmeal and fish oils in order to feed the 'farmed fish'. Every year hundreds of millions of anchovies, for example, are caught specifically to be ground up as fishmeal for farms that will ultimately produce a vastly smaller number of trout or salmon.

Consumers need to radically change their eating habits, yet fish remains the world's most traded food commodity, and global consumption continues to rise. Only the immediate set up of marine reserves covering no less than 20% of the world's oceans could provide any reasonable chance of recovery. However only 0.6% of the oceans are presently protected, and migrating fish have no hope of any respite from human hunting. Furthermore, with the oceans steadily warming, established fisheries will see an even greater reduction in stocks as the remaining populations of many species gradually migrate polewards.

It appears that the numerous repercussions of unrestricted human activity in the world's oceans are magnified at higher latitudes. Fragile marine ecosystems in polar waters do not just have to contend with the stresses of overfishing, but they are also at the mercy of accentuated climate change. Air temperatures off the Antarctic peninsula, for example, have risen approximately 3°**C** in the last 50 years, with sea temperatures in the region beginning to reflect the rise. The warming of the oceans has already had many consequences for marine life here. It has allowed certain predators, for example, to diversify and spread to higher latitudes, threatening numerous marine species that have adapted, over many generations, to colder Antarctic conditions. Larger predators, including king crabs, bony fish and sharks, have spread southwards into regions of the ocean that they would have previously been unable to survive, threatening entire species of Antarctic molluscs, crustaceans and echinoderms which have evolved independently of their mid-latitude relatives for tens of millions of years.

Even more profound however is the direct effect of ocean warming on those polar species that are highly sensitive to environmental change. A rise in temperature of just a couple of degrees is enough to decimate entire populations of Antarctic scallop, shrimp, clam and krill ~ the latter being a keystone species that effectively supports most major oceanic ecosystems. With the loss of ice comes a steady decline in polar algae that grows on the underside of the vast ice sheets. This feeds the Antarctic krill which, in turn, sustain a huge variety of marine species. Indeed the total biomass of Antarctic krill at the start of the 21st century was estimated to be around 500 million tonnes. However, along with the relentless commercial overfishing of krill, ice loss has caused numbers to plummet ~ placing further stress on the ecosystems of the Southern Ocean.

As if overfishing, industrial pollution and climate change aren't enough for many fish populations to contend with, some species face yet another threat ~ genetic erosion. Farmed fish *(that have bypassed the process of natural selection)* have been commercially bred for several decades. However the aquaculture industry has a poor record of containment, and instances of escaped fish eventually displacing local populations are well documented. Yet, despite this, by 2012 the first transgenic salmon were licensed for public consumption in the **US**, giving the green light for genetically-modified fish to be mass-produced for the American market.

Unfortunately the accidental *(or intentional)* release of salmon such as these, has the potential to fundamentally change the species or even wipe out wild populations.

Engineered to carry the human growth hormone ***(hGH)***, these salmon are larger and mature faster than their wild counterparts. As such, if placed within a natural environment they would 'out compete' their native rivals for both food and mates, thus spreading their progeny throughout a wild population faster and more efficiently. However the **hGH** gene also reduces sperm production, often leading to deformity and premature death in young salmon ~ with only around 60% actually reaching reproductive age. Driven into the population through sexual selection, over a number of generations the **hGH** gene would invariably threaten the integrity of the wild salmon, degrading the stock and potentially driving the species to extinction.

Given its current rate of decline, the biodiversity of our living planet is eroding so fast that we are clearly in the midst of a sixth *(and possibly the greatest)* mass extinction of life on Earth. Indeed it is happening with unprecedented speed in the fossil record, with the current extinction rate up to a hundred times greater than it was during any previous mass extinction event. This terrifying loss is profound. Even past mass extinctions triggered by asteroid strikes or supervolcanic eruptions unfolded over thousands of years as complex ecological interactions took time to destroy the ecology of plant and animal species that were not initially affected. The ongoing ***'Holocene extinction'*** however is happening at lightning pace *(in geological terms)*, with the most severe consequences occurring over a matter of centuries rather than millennia. The reason can be found in the underlying cause of this present-day mass extinction: the rapid ascendancy of man.

The loss of numerous large animal species around the world *(that coincided with the colonisation of new continents by modern humans)* during the late Pleistocene, represented an initial spike at the start of a much larger extinction event. For the last 8000 years or so extinction rates, although still comparatively high, began to level off. However, with the advent of industrialisation in the late 18th century, the number of extinctions started to rise sharply once more.

Human expansion over the past few hundred years has put unprecedented pressure on a growing number of ecosystems around the world. Yet the decline of any one species is rarely down to a single cause. More typically, several factors are responsible for a species' demise and today most, if not all, are a direct consequence of human activity. The most common factor documented in recent extinctions is habitat destruction, with the loss of vast expanses of wilderness completely changing the dynamics of countless ecosystems. In addition, the dwindling populations of many endangered species have to contend with the introduction of invasive plants and animals, extensive pollution and of course climate change, as well as over-hunting by a fast-growing human population.

The Holocene extinction is on the cusp of entering an even more deadly phase, with an imminent sudden catastrophe *(or final extinction pulse)* likely to push large numbers of plant and animal species over the abyss. Planetary biodiversity is falling so rapidly that, were the current trend to continue, less than half of all plant and higher-animal species alive today, are likely to survive beyond the 21st century. Moreover the long-term decline of many wild animal species that may initially survive the consequences of human expansion is also assured. With a permanent loss of habitat, many declining populations can never fully recover even if humanity were to simply disappear. Known as *'dead clades walking'*, a growing number of animal populations are forever unable to diversify, leading their species to head inexorably along the path towards total extinction.

Unlike any other extinction event that has gone before, this phase of the Holocene extinction is all-encompassing from the outset. Whether triggered by a cosmic or terrestrial catastrophe, all previous mass extinctions spread around the world as a deadly chain of events that may have taken thousands of years to unfold. The present extinction event however was actually initiated on a global scale. As such, it is the first one, for example, to immediately effect so many different plant species from such a broad range of ecosystems. The potential loss of so much flora, of course, has dire consequences for many species of animal too. For many wild animal populations, the serious fragmentation of habitats, for example, will inevitably lead to genetic erosion. In fact a rapid deterioration is already occurring in the gene pools of numerous endangered species.

Cut off from one another, local populations of endangered animals that only survive in fragmented habitats, will readily reach a point of irreversible decline. With fertile individuals often prevented from ever meeting, a 'bottleneck' can occur in the overall population, leading to a higher percentage of inbreeding. Amongst the many detrimental effects, this causes an increased likelihood of genetic defects in future generations, as well as growing infertility and a weaker immune system ~ exposing the species to new diseases that could potentially wipe out any surviving wild populations. Moreover, with the spread of modern agriculture, many animal species and plant varieties are threatened by 'human-imposed' ecological uniformity ~ also causing the genetic erosion of their surviving wild counterparts,

Pristine ecosystems don't respond particularly well to the human mismanagement of nature, and our species has shown an historic 'lack of understanding'. The remote Hawaiian islands in the North Pacific provide a good example of how blind human interference with the natural world can decimate the ecosystems within it. Hawaii and its smaller neighbouring islands once had the highest concentration of unique species *(existing nowhere else)* of any island chain on Earth. However, since the arrival of the first Europeans in 1778, the islands have lost many hundreds of plant and animal species, and native Hawaiian wildlife today is tragically impoverished. Furthermore, most of the few remaining native plant and animal species that cling on to existence are still under enormous threat. In 2009 for example, of the 192 bird species described as being 'critically endangered' on the **IUCN**'s regularly updated *'Red List'*, 14 were native to Hawaii. Agriculture, logging and the spread of invasive species remain the primary causes of their continued demise.

Of course humanity is not completely oblivious to the damage that we, as a species, are doing to the natural world. Yet most conservation efforts, although well-intended, are wholly inadequate, and attempts to save many species are ultimately doomed to failure. Whilst wildlife reservations, protected parks and animal sanctuaries are largely ineffective, captive breeding programs, for example, do little more than perpetuate the struggles of dying animal populations. Sadly, a growing number of once critically endangered species are becoming extinct in the wild and now exist only in captivity. Effectively being kept alive for 'posterity', the final generations of numerous mammal, reptile, and bird species live exclusively in human-controlled environments. With such a reduced gene pool, remaining individuals run a higher risk of disease, infertility and birth defects. Furthermore, if such species were actually to be reintroduced into their wild, natural habitat, they would be unable to readapt even if conditions were ideal. After just a few generations of captive existence, any subsequent offspring become 'mimetically disadvantaged', as the learned survival techniques of the species are potentially lost forever.

That is not to say that all conservation efforts are a complete waste of time. Indeed human technology has been used to help bring some species *(that we ourselves have pushed to the verge of extinction)* back from the abyss. The two extant species of orangutan are good examples of endangered animals that have been helped by hi-tech conservation. In 2011 the genome of the Sumatran orangutan *(one of the world's most endangered primates)*, was sequenced with a view to protecting its lineage. Although numbering fewer than 6500, the orangutans here were surprisingly shown to have greater genetic diversity than their more numerous cousins in Borneo. From 1997-8 and from 2002-3, huge forest fires throughout much of Borneo had a devastating impact on the island's remaining orangutan populations. Around 15,000 or so Bornean orangutans *(about a third of the entire population)* were under threat as manmade fires in the island's peat swamp forests raged out of control. Having been drained for agricultural use, the land was further dried out by particularly strong El Niño events in those years, and it required considerable effort and co-ordination to save and repatriate thousands of orangutans.

Modern technology, however, can also be used for folly and, although most scientists involved genuinely believe that their work has enormous value for animal conservation, some projects are completely misguided in their approach. Between 2003-9, for example, numerous attempts were made to clone the Pyrenean ibex from tissue samples taken from the last surviving individual. Although the species became officially extinct in 2000, nine years later the first clone to survive beyond birth, breathed life for an entire seven minutes before dying of a serious lung defect. Cloning technology has also been employed in cynical attempts to reanimate the woolly mammoth. Following the discovery of a number of well-preserved specimens beneath the Arctic tundra, the idea of transferring the nuclear material of mammoth cells into the ova of modern elephants to produce clones of the long extinct species appeals to many geneticists around the world. The chances of this actually being possible came a step closer in 2008 when the woolly mammoth became the first extinct animal to have its genome mapped. Now, rather than having to piece together millions of broken **DNA** strands from the soft tissue of preserved mammoths, complete mammoth **DNA** could potentially be synthesised directly from the cells of other living animals.

Such unethical, expensive and ultimately pointless exercises have no hope of ever re-establishing viable breeding populations be they Pyrenean ibex, woolly mammoths or any other extinct animal. Unfortunately the genetic sciences are far more likely to be applied successfully when they manifest as a destructive element of human invention. Indeed with ignorance and greed dominating worldwide human activity, the biospheric integrity of our living planet is declining considerably ~ so much so that it's impossible to imagine that it will not completely collapse sooner or later.

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ii.

*(**Human interference:** environmental complacency)*

Human beings are ultimately responsible for the loss of thousands of plant and animal species around the world over the past few centuries. No other animal throughout Earth's living history has even come close to destroying so many other different species. However we are more than simply the agents of extinction. Today human activity poses numerous existential risks to humanity itself, and our present day actions actually threaten our own long-term survival. Indeed we have presented ourselves *(and countless other species)* with a bleak future of our own making.

So long as present attitudes and lifestyles continue in the world's industrialised nations, we are heading for what has been termed a ***'global anthropogenic ecological catastrophe'***. Yet the future consequences of today's human activity are so horrific to contemplate, that many people conveniently *'switch off'* from the greater reality of environmental decline. The inevitable exhaustion of the planet's resources and its effect on human health across the 'civilised' world, for example, does not seem to carry the urgency it should. Indeed, distracted by things such as politics, religion and the pursuit of private wealth *(all uniquely human past-times)*, for most people such matters appear too distant to be of serious concern. However, the illusory benefits of much human endeavour is completely offset by the fact that the man-made ***'market economy'*** is increasingly suffering from the losses of the Earth's ***'natural economy'***.

Unfortunately for the natural world, the uniquely human perception of national identity has caused us to place self-imposed boundaries around our collective endeavours. Therefore most of our efforts are ultimately geared towards accumulating material wealth for ourselves, our families and our countries *(to differing degrees depending on the society in which we live)*. We adhere to economic systems where perceived monetary value is placed upon desirable goods. Yet ecosystems *(which exist completely independently of human thought)* are invaluable by comparison. In fact we are completely reliant on their continued existence; providing, as they do, 'free' natural resources that actually regulate the atmosphere and climate. Fully functioning ecosystems are responsible for the natural mechanisms that purify water, enrich soils and detoxify waste. Without them, there would be nothing to provide the flow of materials and energy from the biosphere to support our civilisations. Indeed, in economic terms, the world's ecosystems are worth hundreds of trillions of dollars each year ~ dwarfing the **GDP** of all the world's nations combined. Yet it seems we are too engrossed in our own 'sense of importance' to give any serious consideration towards the continued health of our living planet.

Besides our failure, as a species, to protect the environment from our worst excesses, our sheer numbers also place enormous stress on the natural world around us. Indeed the burgeoning human population of today is having a profound impact on the world's ecosystems. Our success as a species is phenomenal, and it really began around 12,000 years ago with the 'birth of agriculture' ~ humanity's first great revolution.

The benefits of agriculture for our Neolithic ancestors were huge. As a species, we no longer had to rely on hunting and foraging for survival, as we now began to get nature to work for us. For the previous 190,000 years or so of *Homo sapiens'* existence, our species *(like every other)* had to endure the often adverse *(and largely unpredictable)* conditions of daily life in the untamed wilderness in order to survive. However, by domesticating and cultivating other species for our own ends, food supplies became more readily available, freeing our minds to contemplate other things. Human beings were now no longer bound to the wild habitats of their prey and, over the following millennia, the intellectual evolution of our species progressed enormously.

Following the establishment of farming, other significant advances soon followed, with early settlements laying the foundations of civilisation. From this development came the need to enhance communication, with the invention of writing systems to strengthen trade and enforce the concepts of ownership and law. Within just a few thousand years, our ingenuity had completely altered our perception of life, leading to the creation of a unique 'human world' where new generations became cocooned within 'civilised societies' that protected them from the wilds of nature. As a result the human population began to steadily rise. After a sustained 'age of reason', the 'Industrial Revolution' *(which began in the 18th century)* opened up a whole new chapter of possibilities for our species, with the exploitation of oil, gas and coal enabling rapid human expansion around the globe.

Today both agricultural and industrial innovation hold together the threads of a global civilisation that continues to grow rapidly. In fact, our ability to exploit the land has proved so effective that, over the course of the 20th century, the global human population tripled in size. Indeed, despite countless conflicts *(and two world wars)*, it grew almost exponentially during the century, reaching a landmark 6 billion people in 1999. However, whilst the human population passed the 7 and 8 billion marks in 2011 and 2022 respectively, the annual growth rate *(for the most part)* has shown a steady decline since 1963. Although at its present rate the number of human beings on the planet has been projected to reach 14.5 billion by 2050, with declining resources likely to affect growth before the middle of the century, most analysts expect it to tail off to nearer 9 billion people by then. Nonetheless continued human overpopulation puts an ever-greater strain on Earth's natural resources, increasing the potential for an unprecedented biospheric disaster.

The second half of the 20th century saw phenomenal advances in science and technology ensuring the growth of a truly global trade network. With dramatic improvements in infrastructure and communication technology complimenting increased production, 'Western-style consumerism' began to spread around the world. An interesting way to look at the effect of human success on the planet is to consider that, in the 1960's, our demand for natural resources equated to approximately 70% of our planet's 'regenerative capacity' to grow *(supplying food and other goods for human consumption)*. Within a decade human activity had crossed the boundary of renewable energy as demand matched, and overtook, the Earth's ability to 'supply'.

By the turn of the 21st century human demand had well exceeded our planet's capacity for sustainable resources, and it now took nearer 16 months for the Earth to replenish what humans used in a year.

Despite a general loss of soil fertility and dwindling water resources around the world however, modern agriculture continues to thrive ~ with crop yields often boosted by technological advancements. Indeed, in the developed world, people enjoy *(and have come to expect)* a steady, year-round supply of fresh *(and largely cheap)* produce. Here consumers have the luxury of being choosy even though their supplies are largely maintained through hugely wasteful food management and distribution systems. But it's not only the populations of developed countries that benefit from technological advance. As agricultural mechanisation improves in developing nations, more virgin forest is consumed to replace old farmland whose soils have often degraded through erosion and poor management. As a result, by the start of the 21st century over ¼ of the planet's land surface area had been taken over as either cropland or pasture, largely replacing vast areas of forest and grassland. Alarmingly, by 2007 however, around 40% of all farmed land had already become seriously degraded.

Considering the irreparable damage that human agriculture has inflicted on the natural world, there is a somewhat poignant irony to the fact that the survival of so many people relies on just a small number of domesticated plants whose continued cultivation is at the mercy of nature. Indeed 90% of all arable farming today is provided for by just over a hundred different plant species. With a combined annual production exceeding 2 billion tons, the top three crops *(wheat, maize and rice)* between them support nearly all urban and rural populations around the world; effectively keeping our species from starvation. But as human numbers grow and resources diminish, productivity cannot be continually boosted, or even maintained indefinitely. World cereal and meat consumption, for example, tripled over the last fifty years of the 20th century, whilst fish catches increased six-fold in the same period. In addition, the extra stresses placed upon the world's ecosystems by climate change and the depletion of mineral resources is likely to have a profound effect on civilisation over the coming decades. With the global food economy almost entirely oil-based, and with oil *(along with groundwater)* becoming increasingly scarce, the eventual collapse of most farmed ecosystems is inevitable.

At present approximately 70% of all freshwater we use is actually consumed by agriculture, and its increasing scarcity presents an ongoing challenge for all of humanity. As distant as it may appear now, the risk of 'global crop failure' is a growing one. In the developed world, agricultural production is sustained by a vast mechanised industry where sophisticated irrigation systems and intensive farming practices enable modern agriculture to feed huge populations. Alas in much of the developing world, where rural populations depend on local subsistence for survival, modern farming technology is generally not available. With a lack of clean groundwater, both crop failure and disease are commonplace, and over a billion people throughout the developing world are still malnourished. Furthermore the prospect of starvation is a real and growing problem for millions every year.

Not only is the distribution of farmed foodstuffs grossly uneven, but modern agriculture itself is a hugely inefficient system for transferring energy from the land to the human population. Indeed around half of all grain produced annually is not actually grown directly for human consumption, but as animal feed *(to sustain cattle and other livestock)*. It is also grown in ever-greater quantities to produce biofuels, in particular ethanol; the mainstay of a ludicrously inefficient process designed to create an alternative to *(and additive for)* petroleum products such as gasoline and diesel fuel.

The ongoing process of human expansion around the planet *(in particular through deforestation)* is responsible not only for a huge loss of biodiversity, but often for the eventual desertification of once fertile land. Oceans, seas and waterways also suffer from an incessant human interference with the land, with nutrient run-off *(especially from fertilisers*), for example, crippling many coastal and marine ecosystems around the world. In many cases eutrophicated coastal waters and estuaries encourage huge blooms of phytoplankton, which can in turn deplete oxygen levels and destroy fish nurseries. But it's not just modern agricultural practices that can poison the habitats of aquatic species, with the discharge of untreated sewerage effluent and industrial waste also bringing hypoxia and death to marine ecosystems all over the world. When you factor in the additional stresses of gradual warming, increased acidity and intense overfishing, the steady rise in the number and extent of dead zones in the world's seas and oceans is not surprising.

Yet the process of globalisation continues unabated, with more of the natural world exploited every year. As new lands are utilised for the purposes of strictly human consumption, so the tentacles of civilisation pervade new regions of unspoiled wilderness, often destroying natural biodiversity and stripping them of mineral resources. Of all resources to have been mined or drilled for human consumption, fossil fuels have had the greatest impact on our species. Indeed modern civilisation has become totally dependant on oil, and the more it grows, the greater its thirst for petroleum and its many derivatives.

The global industrialised production and consumption of oil continues to increase in order to satisfy the demands of modern civilisation. Yet, with around 20% of the human population now consuming some 80% of the Earth's resources, our energy use reflects the profoundly uneven distribution of wealth across the 'civilised world'. Furthermore, modern civilisation is still largely powered by the energy released from burning fossil fuels and, at the present rate of growth, global energy consumption will have risen by over 60% in the first 30 years of the 21st century. However it is believed that, by mid-century, most current oil reserves will be completely exhausted.

Over the coming decades we are likely to see the convergence of various problems *(such as oil and aquifer depletion, climate change, and biodiversity loss)* putting unprecedented stresses on modern civilisation. Yet, in the developed world we continue to play out our lives within the illusory comforts of a false, manmade economy where military spending, for example, is far greater than any conservation budget. Indeed the delusions of our forebears continue to enforce our national beliefs, perpetuating a misguided faith in our unique human world. Alas as a species, we have already left our mark on the living planet by instigating serious ecological decline that will continue long after the global economy has collapsed. In our unending desire to create wealth, we seriously compromise the climatic balance that has enabled us as a species to grow over the last 12,000 years, whilst we continue to dismantle the 'web of life' ~ the very support system upon which all species depend.

It is clear that all life depends on the availability and delivery of water, with each different species having evolved to survive and flourish in any given environment. Whilst the diverse network of currents that encircle the oceans and seas provide vital lifelines for a vast majority of marine life, on land it is weather systems that are crucial for the continued survival of the flora and fauna. Rain supplies the freshwater to most fertile regions and, in areas of water scarcity, its prolonged failure can lead to the desertification of the land ~ and death.

Just as warming conditions can change the strength and position of important ocean currents, so they can alter global weather patterns to the detriment of many thousands of plant and animal species. Indeed the combination of subtle *(but increasingly dramatic)* meteorological changes, along with the incessant clearing of major forests *(and other terrestrial biomes)* is changing the face of the land and putting enormous stress on the living planet. As primary producers, the plant kingdom is depended upon by all complex living organisms from animals to fungi. Yet it is currently believed that one in eight of all known plant species will be at high risk of extinction over the coming century. Herein lies a problem for the health of future generations of ours and many other animal species.

Having come into existence some 55 million years ago, the ***'Amazon rainforest'*** *(the largest and most diverse on Earth)* accounts for more than half of the planet's remaining tropical rainforest and contains over 60% of the world's known plant species. Covering around 2 million square miles *(and shrinking)*, Amazonia is home to over 2½ million species of insect and approximately 5,000 different vertebrate species ~ including around 20% of all known birds and fish. Yet it is being cleared on an unprecedented scale, with over a third of the original forest having disappeared during the 20th century. By the first decade of the current century the Amazon rainforest was disappearing at a rate exceeding 10,000 square miles annually, and it continues to be destroyed ~ with vast swathes of native *(and often unique)* plants cleared to grow crops such as soya, coffee, sugar cane and cocoa. Indeed the creation of fertile crop plantations have increased the exports and strengthened the 'financial economies' of Amazon countries, especially Brazil which also contains what remains of ***'Mata Atlântica'*** *(or the '**Atlantic Forest**')*.

Before the arrival of the first Europeans over 500 years ago, the Atlantic Forest provided unbroken canopy to most of the continent's South Atlantic coastline, and spread several hundred miles inland. However, much of the land it once covered is today occupied by almost 60% of the Brazilian population, with huge areas of lush forest having been cleared to make way for sprawling cities including Sao Paulo, Rio de Janeiro and Salvador. Indeed by the turn of the 21st century, intense human activity had reduced the Atlantic Forest to less than 7% of its original size. Yet it still contains pockets of land that have the highest diversity of plant life found anywhere on Earth.

Unfortunately the ongoing destruction of the Amazon and Atlantic forests has not only decimated the natural habitats of numerous endangered species, but it continues to weaken many important ecosystems that have so far survived. Indeed, in reducing biodiversity and disrupting local weather patterns, the disappearance of so much forest has brought numerous complications to the natural ecosystems that still continue to function in the region. Moreover, the brutality with which humans have 'reclaimed' the land from nature is evident in the *'slash-and-burn'* technique of forest clearing; a method still practised by over 250 million people around the world. The Amazon alone faces an onslaught of almost a thousand manmade fires every day, with poor subsistence farmers having to regularly move to new areas, as cleared regions become susceptible to weed invasion and an inevitable reduction in soil fertility.

Alas, many areas of the Brazilian rainforest are not cleared simply to produce crops or rear livestock in order to feed the country's growing human population. Many goods are farmed purely for export; producing Brazil's enormous trade surplus. Indeed with no shortage of natural resources to exploit, Brazil has embraced the capitalist values and ideals of 'Western-style' commerce and consumerism ~ flourishing as a result. As the country has emerged as a major world economy in the 21st century, virgin forest has made way for everything from huge plantations and industrial developments, to golf courses and exclusive holiday resorts. Yet Brazil is failing miserably to protect the integrity of Amazonia *(the breathing heart of the country and source of its wealth)*. Despite setting aside large areas of land as 'protected reserves', as well as monitoring many of the most threatened regions using satellite surveillance, illegal logging and burning continues at an alarming rate. Guilty of inadequate policing, successive Brazilian governments have effectively promoted national wealth at the expense of the natural environment.

With profit seemingly easier to come by through the indiscriminate clearing of forests for plantations and other forms of land exploitation *(rather than through sustainable management of the flora)*, the major forests of every continent have either been seriously degraded or completely destroyed. In Africa, for example, the unregulated burning of forests for charcoal is commonplace, with unscrupulous traders causing unprecedented damage that has exacerbated famine and disease in many areas. Meantime, the once sprawling rainforests of South-East Asia, have been largely decimated by countries eager to exploit them for economic survival ~ with a formidable logging industry here driven by a huge demand for resources from China and Japan.

Unfortunately it is not only the world's rainforests that have been over-exploited. Even the ***'Boreal forest'*** *(or '**Taiga**')*, the world's largest terrestrial biome, has been significantly degraded by human activity. Storing more carbon than all of the world's temperate and tropical forests combined, the Boreal forest virtually encircles the globe at high northern latitudes, encompassing vast regions of Northern Europe, northern Russia, Mongolia, Alaska and Canada. Biodiversity here is far less than in the tropics, but in terms of plant numbers it is unparalleled ~ still containing almost a trillion ‘largely coniferous' trees. Giving way to vast tracts of frozen tundra, the sparse northern treeline of the forest is rarely visited by humans, however the forest’s southern flanks have been ravaged *(particularly in Russia)* by a huge logging industry that serves an insatiable demand for lumber. The practice of *‘clearcutting’* in the Boreal is commonplace across the continents, where forest land is often replaced with vast monocrop plantations. Farmed for specific capital ventures, the selective harvesting of particular trees and shrubs has changed the face of the land in many forest areas, destroying natural habitats, degrading soils and even altering the microclimates of affected regions.

Agricultural expansion *(in order to increase crop yields or graze more livestock)* is a major cause of tree-clearing worldwide, as is commercial and industrial development. So too is the mining and drilling for a myriad of natural resources that can lay deep beneath the soil. Yet these are by no means the only manmade threats to the existence of forests today. With the human population continually rising, the demand for wood itself is growing annually, with systematic logging responsible for clearing large tracts of forest. As a raw material, wood is exploited for a variety of uses such as in construction, the manufacture of paper and furniture, and of course for fuel. However deforestation is a major contributor to anthropogenic climate change, and by 2010 accounted for some 18% of all carbon dioxide produced by human activity *(second only to the burning of fossil fuels)*. Indeed, at over 5 billion tons a year, the amount of $\mathbf{CO_2}$ released into the atmosphere through deforestation is comparable to the annual emissions of China and the **US** *(the worlds worst polluting nations)*. Moreover it was estimated, in 2010, that carbon was accumulating in the atmosphere at a rate of around 3.5 billion tons annually, reaching a concentration that was some 40% greater than pre-industrial levels.

When a forest is reduced, its ability to absorb large quantities of atmospheric $\mathbf{CO_2}$ is greatly diminished. Of major concern is the role of the world’s forests as a valuable *‘carbon sink’*, which is at serious risk of being lost entirely over the coming century. Indeed when global temperatures eventually rise some 2.5°**C** above pre-industrial levels, environmental stresses on most of the world’s surviving forests could actually induce them to release more carbon than they absorb, causing a dangerous feedback loop that would further accelerate climate change. Not only is the biomass significantly reduced when mature forest is cleared and replaced by smaller, fast-growing crops, but robust native trees often make way for plants grown and harvested specifically for use as *‘biofuels’*. The end result is that even more $\mathbf{CO_2}$ is released into the atmosphere. Alas it has been calculated that, should temperatures rise by a mere 3°**C** above pre-industrial levels, Amazonia would lose around 75% of its tree cover ~ even without purposeful human clearance.

Anthropogenic carbon dioxide is not the only form of pollution to contribute to the destruction of forests. Sulphur dioxide and nitrogen oxides *(expelled from coal-fired power stations and other industrial processes)* can combine with atmospheric moisture to produce *‘acid rain’*. Particularly damaging to the temperate forests of the northern hemisphere, acid rain lowers the **pH** of lakes and groundwater, causing trees to die back and killing freshwater fish in their millions. Indeed it is responsible for enormous damage to the habitats of countless species and, by affecting their basic ability to function, has led to the total collapse of many local ecosystems across the globe. When high levels of acid rain seep into the soil, it can seriously disrupt the life cycles of micro-organisms, such as bacteria and fungi, whose ability to break down organic matter into nutrients is crucial to the nitrogen cycle. Indeed acid rain is known to cause heavy metals such as mercury, lead and zinc to build up in the water and soil of contaminated forest regions. At the start of the 21st century, around 30 million tons of $\mathbf{SO_2}$ was being released into the atmosphere every year by heavy industry ~ with China and the **US** once again the heaviest polluters.

Barring any sudden global catastrophe, the Boreal forest is likely to remain largely intact over the coming century *(albeit in a much altered state)*. However other important biomes will not fair so well. Losing everything from temperate broadleaf forest to tree savannah, the Earth is undergoing enormous change, with a once healthy biodiversity being suffocated by gradual homogenisation. A number of computer models have predicted that, by 2050 for example, the Amazon rainforest, will have almost completely perished as a result of rising temperatures, reduced rainfall, human encroachment and pollution. Alas further depletion of the world's forests is inevitable, with human greed powering their systematic destruction. The combined efforts of governments and environmental organisations worldwide to protect and preserve forest land is far outweighed by the will to exploit it. Yet massive deforestation is ultimately shaping the climate and geography of our planet, contributing greatly to the unstoppable spread of desert and semi-arid scrub.

One of mankind's somewhat less salubrious legacies is our widespread polluting of land, sea and air. Our collective disregard for the natural world *(whether it be at the expense of necessity or convenience)* is slowly killing thousands of important ecosystems across the planet. Indeed, pollution not only reduces biodiversity but ultimately effects human life, with the potential to cause famine and disease. At the start of the 21st century air pollution, for example, was responsible *(directly or otherwise)* for the deaths of some 4.6 million people around the world every year, whilst diarrhoeal diseases associated with poor water quality was killing over 2 million people annually. Moreover both numbers continue to rise at a worrying rate.

Exhaust emissions from internal combustion engines are a major cause of air pollution today, with motor vehicles, aircraft and coal-fired power plants contributing the greatest amounts. Typical pollutants include carbon monoxide ***(CO)***, nitric oxide ***(NO)***, and sulphur dioxide *($\mathbf{SO_2}$)* as well as larger particulate matter such as soot, oil smoke, and diesel particles. All of these have been implicit in the production of smog ~ a manmade phenomenon which has blighted many of the world's larger cities. In addition, the by-products produced by chemical plants, oil refineries, incinerators and other forms of heavy industry are also responsible for deteriorating air quality as well as being major sources of soil and water pollution. The recycling of industrial by-products to make inorganic commercial fertilisers, for example, has led to widespread soil contamination, with product impurities raising levels of toxic metals such as lead, chromium, and uranium *(as well as an array of dioxins)* in 'over-fertilised' farmland.

Furthermore the water table beneath many populated regions of the world is susceptible to contamination from pollutants produced by *(amongst other things)* intensive farming, landfill sites, and damaged sewers. These pollutants can leach into the groundwater *(especially in times of high rainfall)*, and the problem grows as populations expand.

The forms of pollution that humans produce are as varied as their consequences, and it is not just air pollution that readily spreads across the wider world. Over the years the release of industrial and agricultural waste, *(as well as untreated sewage)* into the immediate environment for example, has led to the eutrophication of many lakes and rivers and caused untold damages to coastal waters. Indeed it has contributed to a worrying trend that's seeing dead zones in the world's steadily warming oceans and seas increase in both size and frequency. Meanwhile, another, more 'permanent', type of polluting has increased dramatically over the past 50 years. Resulting from nuclear power plants, weapon research facilities and armed conflict itself, radioactive contamination of land and sea is a long-term, and potentially catastrophic, form of pollution.

The serious polluting of a region can be gradual *(as pollutants build up over time)* or it can happen overnight, and in peacetime, sudden pollution most commonly occurs as a result of human error. Serious accidents that have resulted in major environmental disasters include the running aground of the Liberian super-tanker ***'Amoco Cadiz'*** in 1978 which shed almost 220,000 tons of crude oil into French coastal waters off Brittany. In terms of human life, the accidental leak of methyl isocyanate and other highly toxic gasses from the ***'Union Carbide'*** pesticide plant in Bhopal, India in 1984 is one of the deadliest industrial disasters ~ killing up to 18,000 people and injuring over half-a-million more.

These are just two of the countless 'accidental' environmental catastrophes to have played out within human history. However, although many such disasters have occurred through negligence or incompetence, not all were simple accidents. Conflict, for example, brings out a darker and more ignorant side to the human psyche and the intentional pollution of enemy territory is not uncommon in war. Indeed, the worst single case of oil pollution occurred during the 1991 ***'Gulf War'*** when retreating Iraqi forces sabotaged over 700 Kuwaiti oil wells. Most were either set alight or severely damaged, resulting in the loss of over 200 million tons of crude oil. Of this, almost 7 million tons of unignited oil pooled into over 300 'oil lakes' which contaminated over 40 million tons of sand and earth ~ threatening Kuwait's limited groundwater resources. Other wells burned out of control for up to 10 months, causing a dramatic fall in air quality, and it even affected regional weather patterns over much of the Persian Gulf.

Twelve years later, in Iraq itself, another 'deliberate' disaster resulted in the largest single manmade emission of sulphur dioxide into the atmosphere. Fire *(caused by a rocket-propelled grenade attack)* at the ***'Al-Mishraq'*** chemical plant near Mosul in 2003, burned out of control for almost a month and released around 600,000 tons of the noxious gas, causing serious respiratory problems within many local populations. It also destroyed vegetation over a wide area, proving disastrous for wildlife in the region. Put in to perspective however, the amount of $\mathbf{SO_2}$ released by the Al-Mishraq fire was more than that expelled during most volcanic eruptions, yet it amounted to just a fraction *(less than 1/30th)* of the annual $\mathbf{SO_2}$ emissions produced by the United States alone.

When an environmental disaster unfolds over time, it may not appear as vividly horrific as a sudden catastrophe, but its effects can be just as devastating and far reaching. The widespread and indiscriminate use of the genotoxic pesticide ***'DDT'*** for over 30 years, for example, has damaged countless ecosystems, many of which are unlikely to ever fully recover. Readily absorbed in soils and sediments, **DDT** *(dichlorodiphenyltrichloroethane)* persists in the environment and accumulates within the food web. Implicit in the collapse of many predatory bird populations, it was also found to be toxic to a wide range of organisms *(especially marine animals)*, leading to a ban on its agricultural use. However **DDT** continues to be widely used to control malaria, with India currently the world's largest producer. Yet it is not only hazardous to wildlife, but can have a significant impact on human health. Linked to everything from Alzheimer's and diabetes to various cancers and reproductive defects, direct exposure to **DDT** is also known to readily cause developmental neurotoxicity in young children.

DDT is just one of many countless pollutants that we have introduced into the environment, but not all are complex synthesised compounds like this. Indeed, some of the most toxic pollutants derive from basic elements such as arsenic, lead, and mercury which have been extracted from mineral deposits and exploited for our own means. Found throughout the world *(mostly as cinnabar)*, mercury, for example, has been mined for at least 2,000 years, but its production and release into the environment has skyrocketed since the start of the industrial age. Indeed mercury contamination as a gradual, but persistent, pollution is at the heart of numerous environmental disasters.

Posing a danger to most life forms when ingested or inhaled, mercury can also be absorbed through the skin, and debilitates the central nervous system. Exposure can lead to a huge array of neurological disorders and congenital diseases, yet by the 1990's levels of atmospheric mercury had risen five-fold since the start of the industrial age. Most mercury emissions today come from the newly industrialised nations of South-east Asia, where regulations concerning its control are generally less stringent. Here, activities such as gold mining and cement production *(as well as burning fossil fuels)* are major sources of mercury pollution.

Like **DDT**, mercury pollution persists in the environment. Once it becomes ingested or absorbed by a living organism, mercury will enter the food chain, with residues becoming ever more concentrated the further up it travels. It is this bio-accumulation of mercury that makes it especially hazardous to the top predators within a polluted ecosystem. A particularly harrowing, historic example of mercury poisoning involves the ***'Chisso Corporation'*** chemical plant in Minamata, southern Japan. In 1932 the factory started production of acetaldehyde, using mercuric sulphate as a catalyst. For

36 years it continuously dumped wastewater containing, amongst other things, *'methyl mercury'* initially into the local harbour and, later, directly into the Minamata River system. An organo-metallic compound, methyl mercury is a highly toxic pollutant which accumulated in the local food web. Being water-soluble, it was absorbed by fish and shellfish in and around the Yatsushiro Sea, with the waters off Minamata Bay becoming extensively polluted. Indeed it is unlikely that fish stocks here will ever fully recover.

With seafood the staple diet for many people in the region, by 1956 strange new illnesses had begun to emerge amongst local human and animal populations. Affecting a growing number of people, it would become known as *'Minamata disease'*; a neurological syndrome arising from severe mercury poisoning. Yet, although a link was soon established, the practice of discharging toxic waste directly into the local water systems continued for another 12 years.

Based at the heart of a small factory town. 'Chisso' was not only the biggest employer in the region, but was highly influential in local politics ~ allowing it to be negligent in the extreme. It failed to co-operate with investigators, withheld vital information, actively attempted to undermine research, and even employed *'yakuza'* to harass victims looking for compensation. In order to deflect bad publicity aimed towards its operations, in 1959, Chisso opened a totally ineffective purification system and proceeded to discharge its waste directly into the Minamata river. As a result of the company's deception, fish stocks at the mouth of the river collapsed and new cases of the disease were now reported in fishing villages and other settlements further along the coast. Although the true number of victims is difficult to quantify, it is likely that at least 2,000 people died as a result.

Mercury is not the only toxic element to register elevated levels as a result of human activity. Indeed an anthropogenic bio-accumulation of 'heavy metals' is occurring in every environment in the world. Levels of thallium, lead and cadmium, for example, have been building up in the Arctic ice core over the past two centuries, due largely to coal burning in the Northern Hemisphere. Where Western Europe and North America once contributed the bulk of this contamination, now southern and South-east Asia have become the greatest sources of pollution.

Although some toxins can occur naturally and do not necessarily persist in the environment, many are also produced anthropogenically. By the turn of the 21st century human activity accounted for a small but significant proportion of the total global emissions of natural poisons such as hydrogen sulphide, cyanides and arsenic. Although naturally present in soils, arsenic, for example, can leach into groundwater that is depended upon by millions of people. Not only have concentrations risen as a result of industrial pollution, but as populations grow so more wells are dug, raising the likelihood of contamination. Arsenic poisoning now affects up to 140 million people worldwide, with children in developing countries at greatest risk. Indeed almost 850,000 children in Bangladesh alone die every year from polluted drinking water, much of which is contaminated with arsenic.

Today, in addition to heavy metals and toxic metalloids, a wide range of 'persistent, bio-accumulative toxic compounds' continue to pollute the natural world. Amongst the most dangerous are a group of compounds known as the *'polychloronated biphenyls' (PCBs)* which once had extensive industrial uses. Employed in everything from adhesives and paints to cooling systems and flame retardants, the useful properties of **PCB**s were exploited for over 100 years. First synthesised in 1881, they were widely used up until the late 20th century, with the total global production estimated to have been approximately 1.5 million tons. However, their toxicity was recognised as early as 1937, and exposure to **PCB**s was subsequently linked to things such as cancer, liver damage, and immune system disorders ~ leading to their eventual worldwide ban in 2001. Nevertheless many **PCB**s remain in the environment, having been released in huge quantities over the past century.

Insoluble in water and extremely slow to decompose, most remaining **PCB**s have gathered in soils and marine sediments, creating hidden toxic 'black spots' in affected environments. In addition, illegal dumping of **PCB**s in landfill sites, wastewater sludge, and sewage have further dispersed these dangerous pollutants. There are, for example, historic cases of raw sewage contaminated with **PCB**s being treated, and converted into bio-solids which have then been applied to farmland. However, while they are not water soluble, **PCB**s can be absorbed through the skin. Indeed they are readily dissolved in fats and, should they become ingested, will persist within the food chain ~ with the potential to poison local populations of *'top predator'* species for many generations.

The **PCB**s *(like **DDT** and dioxins)* can be classified as ***'persistent organic pollutants'*** *(or '**POPs**')* ~ organic compounds that are resistant to environmental degradation. Whilst toxicity levels of these different compounds vary, all have entered the environment through human activity, and all have the potential to harm functioning ecosystems. **POP**s include a wide range of manufactured organic compounds used in the production of things such as pesticides, solvents and pharmaceuticals. However, because they have a tendency to bio-accumulate in the fatty tissues of living organisms, their uses today are banned or highly restricted. Yet traces of various pesticides, for example, can still be found in up to a third of all food consumed ~ even in developed countries. Alas the illegal *(and uncontrolled)* agricultural use of **DDT**, for example, continues in several parts of the world to this day, despite ratification by 179 parties, in 2001, of the ***'Stockholm Convention on Persistent Organic Pollutants'*** ~ a **UN** treaty to eliminate or restrict the production and use of such compounds.

It is clear that chemical pollutants continue to pass into the environment and, in many parts of the world, the rate of pollution is increasing ~ further contaminating the food web. Again, people living in developed countries are not immune. Though parents may endeavour to bring up their children in a sterile environment, it is not uncommon for traces of industrial poisons, for example, to enter the food chain. Passed on to babies through breast milk, such contaminants can have the ability to disrupt the hormonal balance and brain development of young children. In addition, drug residues are often present in many human foods, with chickens and other livestock a major source. Indeed around 20% of all chicken meat is infected with drug residues that are ultimately harmful to human health. When you also consider the sustained overuse of antibiotics on livestock, then the growing risks to human health are plain to see.

It is a combination of climate change and pollution however that brings the greatest long-term risks to human health. As global temperatures rise, so weather extremes *(as both drought and deluge)* become more commonplace. In the 2010's, for example, North-western Europe and parts of Southern Asia, experienced weather that was far wetter than normal, with intense low pressure systems occurring with greater frequency. As a result of excessive rainfall, the flooding of wide areas of land caused *(and continue to cause)* a number of health issues. With sewers inundated with water from run-off, rats and other 'pests' are more likely to be driven into the open along with their fleas; which can be the vectors for deadly disease. Not only can polluted floodwater contain a wide range of bacteria, waterborne parasites, and neurotoxins, but wetter, warmer weather allows mosquitoes and other insects capable of spreading infectious pathogens to thrive. In developing countries, particularly within poorer regions, communities are increasingly likely to be ravaged by pestilence and disease, whilst in developed nations it is native wildlife that faces the most immediate danger.

Whether it is cement dust in the air, mercury in the soil or pesticide residues in the water, human activity has fundamentally changed the environments that support countless delicate ecosystems. Often carried in sewage, nutrient pollution *(as well as countless chemical pollutants)* has built up in the environment as a result of the excessive use of everything from inorganic fertilisers to household detergents. Discarded pharmaceuticals, solvents and other chemicals can seep through the earth, severely damaging the micro-environment *(and therefore subtly altering the entire ecology)* of a dependant ecosystem. Many soaps, toothpastes, and deodorants for example, contain the antibacterial agent ***'triclosan'*** which attacks *(and has considerably reduced the proliferation of)* various bacteria that would ordinarily break down other pollutants within the environment.

It is the practice of ***'intensive farming'*** however that *(along with various industrial activities)* produces the most extensive waste ~ with pesticides, herbicides and fertilisers yielding numerous agricultural pollutants. The widespread use of fertilisers, for example, has introduced vast quantities of nitrogen and phosphorus to the environment *(levels of which have trebled since the start of the industrial revolution)*. Indeed in just the last few decades of the 20th century, human activity effectively doubled the amount of nitrogen and phosphorous available to plants globally. An extensive form of nutrient pollution, the excessive fertilisation of farmland can readily upset the balance of nature and have a massive impact on surrounding wildlife. The introduction of extra nutrients to the soil allows fast growing plants to dominate, reducing the availability of sunlight to smaller or slower-growing native species, with the effect that plant diversity is seriously compromised. Indeed since the advent of industrial agriculture, reactive nitrogen fertilisers have caused atmospheric levels of compounds such as ammonia *(NH_3)* and nitrous oxide *(N_2O)* to treble. Huge volumes of both are also produced in *'mega-livestock farms'*, with N_2O a major contributor to smog and acid rain, and NH_3 a powerful greenhouse gas that also causes ozone depletion in the lower stratosphere.

Nutrient pollution does not only effect soil and air quality, but it also severely compromises the health of the world's rivers, seas and oceans. Run-off from nitrate fertilisers and livestock effluent has boosted the growth of algae along the waterways and coastlines of many industrialised nations, often causing the extensive eutrophication of local waters. Massive algal blooms will force out slower-growing plant life and use up valuable oxygen in the water. Moreover, when they die and decompose in large numbers, they produce vast quantities of hydrogen sulphide *(H_2S)*, which seriously degrades water quality, killing fish populations and further reducing biodiversity as a whole.

Hypoxic conditions have become increasingly prevalent in parts of the Adriatic, Baltic, and Black Seas, for example, devastating many local fisheries here. Indeed human activity on land has led to a serious depletion of oxygen in countless waters of the world. Perhaps the most infamous example of this is the seasonal *'dead zone'* which opens up in the Gulf of Mexico every year. First investigated in 1970 *(although the phenomenon was initially noticed on a small scale twenty years earlier)*, the Gulf of Mexico dead zone can, today, cover many thousands of square miles. The Mississippi River system *(which forms a huge drainage basin covering over 40% of continental United States)* empties vast quantities of agricultural nutrients into the gulf, causing severe oxygen depletion in the coastal waters off Mississippi, Louisiana, and Texas, to become an annual occurrence. As a result, many marine ecosystems in the Gulf of Mexico have either collapsed or been severely damaged, with fish stocks in many regions unlikely to ever fully recover.

The amount of marine dead zones around the planet has approximately doubled every decade since the 1960's. Indeed, by 2005 over 150 dead zones were recorded near vulnerable coastal regions, and by 2015, that number had surpassed 400. This is not really surprising when you consider the sheer quantity of pollutants that find their way into the sea each year as a result of industrial and agricultural waste. Indeed it has been estimated that, prior to industrialisation, the world's inshore waters and coastal regions held up to ten times the volume of marine life than is present today. Furthermore our persistent release of $\mathbf{CO_2}$ into the atmosphere has also caused irreversible damage to extant aquatic ecosystems all over the world.

With around a third of all anthropogenic $\mathbf{CO_2}$ dissolved by the world's oceans, the acidity of seawater is slowly increasing, and will cause considerable harm to calcifying organisms over the coming decades. Indeed many species of mollusc and coral, for example, are likely to disappear throughout the present century, as are vast numbers of minute shelled zooplankton ~ a vital food source for countless marine species. Whilst ocean acidification is likely to continue as ever more $\mathbf{CO_2}$ is absorbed, eventually a saturation point will be reached, and the ability of the world's oceans to uptake excess $\mathbf{CO_2}$ will be greatly reduced, accelerating the pace of global warming. Alas today only about 4% of the world's oceans remain undamaged by human activity, with overfishing, pollution and the destruction of marine habitats drastically changing the dynamics of the biosphere.

Manufactured in vast quantities, *'plastic'* incorporates a wide range of manmade materials that have become a major form of pollution. Consisting of largely synthetic, organic polymers, plastics are not readily broken down by nature and can persist in the environment for centuries. Whilst certain bacteria and fungi can consume particular types of plastic, it tends to degrade very slowly ~ readily building up when improperly discarded, particularly in marine environments. Indeed with well over a billion tons of plastic waste having been dumped since the 1950's, up to 80% of marine debris is now plastic. Nowhere is this more evident than in the middle of the world's largest ocean.

The ***'North Pacific Gyre'*** is the biggest of five oceanic gyres ~ huge 'vortices' around which prevailing ocean currents circulate. Whilst the water column within the gyre remains relatively stationary, it is encircled by a clockwise pattern of currents that draw in flotsam and other floating debris from Pacific coastal regions. As a result huge amounts of marine pollution from as far afield as the western United States, East Asia and Japan accumulates in the gyre. Mostly consisting of plastics, much of this marine debris does not biodegrade, but gradually disintegrates into smaller pieces. As it fragments, plastic debris takes the form of pellets which are worn ever-smaller over time ~ eventually becoming minute particles just a few microns across. But even at a molecular level these polymers are not able to be digested by any feeding animal, and threaten to 'choke' the local food chain.

Much of this pollution began life as everything from plastic toys, drink bottles, and disposable lighters, to carrier bags, packaging, and microplastic fibres from washing clothes. Accumulating in the marine environment, these plastic particles can also absorb other contaminants that are hazardous to life. By attracting a variety of hydrophobic chemicals, waste plastic becomes a 'magnet' for persistent organic pollutants such as **DDT**, **PCB**s, and other polymer additives. Indeed, it serves to magnify the concentration of these pollutants which can readily end up in the guts of living organisms. Alas when smaller than a millimetre across, plastic also resembles zooplankton, and is readily eaten by jellyfish and other marine predators, allowing it to enter the food chain.

Known as the ***'Great Pacific Garbage Patch'***, a vast region of the gyre is littered with a mass of floating plastic debris which covers an indeterminable area of the North Pacific. With concentration levels greatest at centre of gyre, estimates regarding the size of the 'garbage patch' vary significantly. These range from an area equivalent in size to Texas, to one twice the size of the continental United States *(over 8% of the entire Pacific)* depending on perceived levels of contamination. One thing is certain however ~ it is continually growing in size. With much of the pollution lying just below the surface of the water as a translucent mire, it is not readily detectable by satellites, however from the perspective of a ship passing through, it appears as an almost never-ending sea of plastic waste.

The Great Pacific Garbage Patch is presently believed to contain somewhere in excess of 100 million tons of plastic debris. It is inevitable, therefore, that pieces of plastic often end up in the stomachs of feeding animals. In fact it has affected huge numbers of marine mammals including whales, seals and sea lions, whilst local populations of sea turtles and albatrosses have plummeted as a result ~ with many species of seabird particularly vulnerable. Indeed plastic debris is thought to cause the deaths of over 1 million seabirds each year across the world. In 2008, for example, it was estimated that around 90% of all European fulmars died with plastic in their stomachs.

Deep within the North Pacific Gyre, just a few hundred miles south of the main convergence zone for debris, lies the Hawaiian archipelago which stretches for around 1500 miles. As a result of their location, the islands here are susceptible to marine pollutants which are regularly washed up on their shores. However, it is the smaller uninhabited islets and atolls in the far north-west of the island chain that suffer most from accumulations of plastic debris. With its shorelines littered with plastic, wildlife on the remote ***'Midway Atoll'*** has paid a particularly heavy price for human success, despite being over 2000 miles from the nearest continent. A major nesting site for millions of seabirds *(including several species of endangered albatross)*, Midway Atoll has become a 'death trap' for breeding pairs, with nearly all fatalities found to have sizeable pieces of plastic in their digestive systems. Indeed around a third of albatross chicks from each generation either choke or starve to death as a result of this 'uniquely human' marine debris.

Huge gyres also exist in the South Pacific, Atlantic and Indian Oceans, and accumulations of plastic are growing within all of them. In fact, per volume, there is now six-times more plastic than zooplankton in the world's oceans, and quantities are not likely to fall anytime soon. Indeed, by the start of the 21st century, the global production of plastic materials had increased fivefold since the mid-1970's. Yet the incessant polluting of our seas and waterways cannot continue without risking potentially catastrophic consequences. Compounded by global warming and overfishing, the health of the world's oceans is deteriorating rapidly, and excessive volumes of plastic only serves to further deplete the oxygen levels of contaminated waters. Not only can this make huge areas of ocean uninhabitable, but it has the potential to 'kick start' an oceanic anoxic event.

There are other pollutants that are not entirely man-made like plastic, but whose harmful effects are exacerbated by additional human production. One particularly damaging by-product of modern civilisation is ozone *(O_3)*, an allotrope consisting of three oxygen atoms whose natural existence is actually beneficial to life. Produced by the reaction of solar rays with more stable oxygen molecules *(O_2)* in the upper atmosphere, ozone forms a thin layer within the stratosphere which shields the planet from harmful ultraviolet radiation. Yet, the production of ground-level ozone by humans can have a far-reaching negative impact on both plant and animal life.

A powerful oxidising agent, ozone has various industrial uses. It is utilised as everything from a bleach, a disinfectant, and a deodoriser, to a reactant *(particularly in the preparation of pharmaceuticals and synthetic oils)*. The incidental production of ozone can also occur during electrical discharge, with high voltage equipment ranging from laser printers and photocopiers to arc welders and electric motors adding to ground-level quantities. However, it is when ozone is produced by the action of sunlight on air pollutants such as exhaust fumes, that it can cause the greatest damage to living organisms. Ozone can create respiratory problems in concentrations as low as 60 parts-per-billion ~ leading to everything from asthma and bronchitis in humans to stunted growth in plants. Indeed the anthropogenic production of ground-level ozone can interfere with the process of photosynthesis, and is known to cause a significant reduction in crop yields whenever the air quality is compromised by urban pollution.

Along with various *'volatile organic compounds' (VOCs)*, ozone is a main constituent of photochemical smog, and has become a serious health hazard in many urban areas. From Paris to Shanghai, and Los Angeles to Mexico City, photochemical smog periodically chokes major cities around the world. It is mainly caused by the reaction of sunlight on nitrogen oxides and **VOC**s, and readily builds up when warm, still conditions prevail in areas where traffic volume is heavy. However as the century progresses, photochemical smog is becoming less restricted to large cities. With its effects magnified by an increasing amount of industrial pollutants and man-made wild fires, modern smog now threatens many rural areas in the northern hemisphere, and has the potential destroy crops on a massive scale. The incessant burning of peat forests in Southeast Asia, for example, has amplified the growing problem of photochemical smog in the region.

Whilst the production of ozone at ground level is a growing health issue, the loss of ozone in the upper atmosphere is becoming an even greater problem. A relatively unstable molecule, atmospheric ozone is continually being produced by solar radiation and removed by reaction *(with free oxygen atoms)*. Although there is a seasonal variation in its thickness, the ozone layer plays a fundamental role in protecting Earthly life all year round by absorbing ultraviolet-**B** rays from the Sun. Ranging from approximately 18 miles above sea level in the tropics to 12 miles high over polar regions, the ozone layer filters out nearly all medium-frequency **UV** light, even though ozone levels peak at no more than 80 parts-per-billion within the layer.

Seasonal fluctuations aside, concentrations within the ozone layer have remained steady until relatively recently. However human activity has introduced various pollutants which liberate *'ozone-depleting halogens'* when they are broken down by solar radiation at high altitude. Once used in the manufacture of everything from refrigeration and air-conditioning units, to solvents and aerosol propellants, chloroflourocarbons ***(CFCs)*** and hydroflourochlorocarbons ***(HCFCs)*** are perhaps the most potent of such pollutants. **CFC**s and **HCFC**s release atoms that catalyse ozone decomposition when they are dissociated by **UV** light. Reducing the overall mass of ozone in the atmosphere by around 4% every decade, free radical catalysts such as atomic chlorine ***(Cl·)***, bromine ***(Br·)*** and nitric oxide ***(NO·)*** set up chain reactions that can break down hundreds of thousands of ozone molecules before finally leaving the stratosphere. Despite the phasing out of many ozone-depleting substances, chlorine, for example, can persist in the upper atmosphere for several decades and, with industrial emissions remaining high, the ozone layer continues to be compromised by human complacency.

Whilst the ozone layer has begun to thin in recent decades, ozone depletion is most dramatic over the polar regions. Every year since 1976, a hole in the ozone layer has opened up over the Antarctic, exposing this fragile wilderness to raised levels of solar radiation. Not actually discovered until 1985, the Antarctic ozone hole appears every spring as frozen pollutants are released by the returning sunlight. Given the right conditions, these 'halogen catalysts' can persist for a long time within the lower stratosphere, preventing ozone replenishment and allowing the hole to grow ever larger. Whilst the ozone hole grows and shrinks with the seasons, the annual trend is one of increasing size, despite international restrictions on ozone-depleting substances briefly stalling its growth in the late 2000s,

Severe ozone depletion occurs over Antarctica and the Southern Ocean every year, and by the early 21st century, springtime levels of ozone here were typically being reduced by up to half. 2011, however, was an exceptional year for ozone loss, with as much as 80% of ozone over the polar regions being destroyed. In fact the Antarctic hole grew large enough to expose the southernmost regions of Australia, New Zealand and South America to excessive **UV** light. In the same year prevailing weather conditions over high Northern latitudes had also caused a hole to open up over much of Greenland and Scandinavia for the first time, with a third, smaller hole also opening up over Tibet and the Hindu Kush. Indeed, the total amount of ozone in the stratosphere in 2011 actually depleted by over 40%.

Besides causing things such as skin cancer *(including malignant melanoma)*, cortical cataracts and severe sunburn, exposure to the **UV** light that would otherwise have been removed by ozone can potentially destroy entire ecosystems. Indeed a complete loss of the ozone column above land or sea compromises the immune systems of all kinds of species. Critically, in Antarctic waters, the annual ozone hole exposes vast numbers of plankton to deadly ultraviolet radiation ~ damaging a fundamental pillar of the oceanic food chain.

Although concentrations of **CFC**s in the atmosphere, for example, are gradually falling *(thanks largely to the work of the 1987 **'Montreal Protocol'**)*, many ozone-depleting pollutants can endure for decades and, so long as industrial production continues, it is unlikely that the ozone layer will ever fully recover. Yet, just as **CFC**s and halons have been phased out in accordance with the **UN** protocol, new chemicals, including hydroflouorocarbons *(HFCs)*, have been produced to replace them. Whilst **HFC**s may not damage the ozone layer, they can be even more harmful to the atmosphere, playing an increasingly impactful role in climate change. As a greenhouse gas **HFC23**, for example, is almost 12,000 times more potent than **CO_2**.

Pollution, it seems, is an inevitable consequence of human activity. Indeed, in order to sustain such a large global population, human beings cannot help but bring about environmental imbalance. Alas, for every other extant species, our ability to solve problems using science *(and a limited rationale)* has enabled us to manipulate different environments to suit our own 'selfish' needs. Moreover, our industrial exploitation of natural resources has persisted for the last two centuries, and grown significantly over the past few decades. Everything in the natural world that is perceived as having practical and/or aesthetic value has been exploited. With the discovery of nuclear fission in the late 1930's, we even began to manipulate the natural world at a subatomic level. It is from this exploitation of atomic energy that 'radioactive waste' *(which includes the most hazardous, long-term, forms of pollution)* has arisen.

Known as 'radioactive decay', the spontaneous release of ionising radiation by unstable atoms can be extremely hazardous to all living organisms. Yet, since the 1950's, the importance of nuclear power *(and other forms of atomic energy)* to the modern world has introduced a whole new type of anthropogenic pollution into the environment. Although relatively small in quantity *(when compared to the volume of pollution caused by fossil fuels)* most radioactive waste cannot be safely disposed of, and is either 'indefinitely' stored in deep geological repositories or reprocessed at huge expense. To date however, much has simply been dumped in the environment, most commonly at sea. Although international agreement now forbids ocean disposal, a vast amount of high level waste products *(including the spent uranium rods from numerous nuclear power stations)* have been dumped this way.

The toxicity of a radioactive substance is proportionate to its rate of decay, which is generally measured in terms of a 'half-life' *(the time taken for it to radiate half of its energy)*. The severity of biological damage it can bring depends on the type and intensity of radiation to which an individual is exposed, as well as the length of exposure. Besides extreme burns *(both externally and internally)* prolonged exposure by humans to most forms of radioactive waste will result in skin lesions, hair loss and severe nausea. Yet radioactive contamination can continue to cause harm to living tissue long after the source of radiation has been removed. The most immediate forms of radiation poisoning *('acute radiation syndrome')* can cause everything from internal bleeding to severe neurological disorders. In the longer term it can lead to numerous cancers *(including various forms of leukaemia)* as well as debilitating chromosome mutations that can cause birth defects ~ thus affecting the subsequent generations of an irradiated individual. Furthermore, the slow decline brought about by *'chronic radiation syndrome'* through low, but prolonged, doses can be just as hazardous.

Of course there have been numerous nuclear accidents *(caused either by human error or natural disaster)* involving the partial or full meltdown of a nuclear reactor. Of the many serious incidents, the most notorious include those at power plants on ***'Three Mile Island'***, Pennsylvania, **USA** in 1979, in ***'Chernobyl'***, Ukrainian **SSR** in 1986, and in the town of Ōkuma, ***'Fukushima'***, Japan in 2011. These, and many others, have released considerable quantities of radioactive by-products into the environment. Rated as major accidents on the *'International Nuclear Event Scale'*, the Chernobyl and Fukushima incidents, for example, were catastrophic, each contaminating large areas of land and sea with manmade radioisotopes caesium-137 *(half-life 30 years)* and strontium-90 *(half-life 29 years)* ~ both of which have an inconspicuous but deadly presence in nuclear fallout.

Nuclear reactors are by no means the only producers of radioactive pollution. The tailings produced from uranium mining, for example, are known to contaminate groundwater and leach pockets of hazardous radon gas. Various industrial and medical uses of nuclear technology also produce radioactive pollution. Most of this however is classed as either 'intermediate level waste' *(which is generally stored underground)* or 'low level' waste *(which is often routinely incinerated)*. It is radioactive waste from the numerous military applications of nuclear technology that can cause the greatest harm to the environment. The use of 'depleted uranium munitions' and the testing of nuclear armaments, for example, can have a huge and long lasting environmental impact ~ with contaminated areas extremely difficult to clean up.

One such place is ***'Lake Karachay'*** in the Chelyabinsk province of Russia, which is regarded as one of the most polluted regions on Earth. Situated in the southern Ural Mountains, from 1951 this small lake *(along with the 'Techa River')* was used as a dumping site for radioactive waste from the nearby ***'Mayak'*** nuclear reprocessing plant and weapons facility that serviced the Soviet military. In the parts of the lake where most of the effluent was discharged, radioactive levels remain lethal for most organisms ~ with little more than thirty minutes exposure here enough to kill a human. A prime example of mankind's destructive disregard for the environment, the Mayak complex was hurriedly built at the start of the Cold War in great secrecy and with little regard to safety. Indeed a massive chemical explosion of radioactive waste in an underground storage vat in 1957 contaminated thousands of square miles of land. Moreover, since the early 1960's Lake Karachay *(like many others in the region)* also started to shrink in size due to climate change, resulting in more and more sediment drying out over time. This was particularly noticeable during a drought in 1968, when the wind carried radioactive dust particles to nearby populations, irradiating hundreds of thousands of people. Since then, the lake bed has been filled with thousands of large concrete blocks in a crude attempt to prevent further escape of the shifting sediment.

The technologies of war, it seems, can cause immense 'collateral' damage to the natural environment, and it is not just from nuclear pollution. The city of ***'Dzerzhinsk'*** in western Russia, for example, was the site of several Cold War chemical weapons factories from 1941, and today remains a centre for chemical production in modern Russia. With hundreds of thousands of tons of chemical waste buried in and around the city over many decades, it is little wonder that its citizens endure a particularly low life expectancy. Indeed there are numerous toxic landfill sites in Dzerzhinsk, and the city remains heavily polluted, with high background levels of dioxins and other persistent organic chemicals. Local authorities are even engaged in a constant battle to prevent serious contamination of the water supply with dangerous poisons such as arsenic, hydrogen cyanide, and lead. Of course the ecological consequences for the region are dire.

When these weapons of war are actually used in anger, then the ramifications for nature can be even more dramatic. The widespread use of the powerful herbicide *'Agent Orange'* by American forces during the Vietnam War, for example, destroyed countless ecosystems. A highly effective defoliant, it was used between 1962-71, primarily to destroy vast swathes of forest in order to deprive the Viet Cong of ground cover and sources of food. Crops grown in regions controlled by communist forces were also targeted, with Agent Orange repeatedly sprayed in high concentrations ~ destroying over 39,000 square miles *(some 25 million acres)* of agricultural land, and causing widespread famine amongst local civilian populations. Ultimately the use of Agent Orange killed and maimed hundreds of thousands of people, and affected the health of up to a million more. By 1971, around 12% of Vietnam had been sprayed with Agent Orange and other toxic herbicides, and with the biodiversity of numerous ecosystems damaged beyond repair, reforestation is unlikely to occur in many areas of the country. Not only have many ancient forests been replaced by smaller and faster-growing 'opportunist' species, but dioxins still persist in the soils and sediment throughout much of Vietnam ~ directly as a result of offensive **US** actions over half a century ago.

Today however, it is the persistent pollution of peacetime activities that holds the greatest threat to the health of the natural world. As our insatiable thirst for energy relentlessly grows, agricultural and industrial productivity is sustained by the combustion of fossil fuels. Fast-depleting natural resources, oil, coal and natural gas produce a wide range of harmful air pollutants when burned, yet they ultimately support the lives of billions of people. Fossil fuels were, of course, a vital component of the Industrial Revolution, and continue to power heavy industry around the world. Once seated firmly in Europe and North America, the heart of industrial development has now shifted towards Asia, South America and Africa as the exploitation of numerous natural resources gathers pace in developing economies. It is here that heavy industry has brought about a significant rise in pollution levels.

Over the past few decades, polluting 'black spots' have appeared throughout many parts of Asia as a result of industrial development. Built on the site of a former 'labour camp', ***'Norilsk'*** in Arctic Russia, for example, sits on one of the largest nickel deposits on Earth, and has become a sizeable industrial city, The mining and smelting of nickel ore is the foremost industry in the region, but rich deposits of other minerals *(including copper, platinum and coal)* are also mined here. As a result Norilsk has today become one of the largest single anthropogenic sources of sulphur dioxide in the atmosphere, and is arguably the most polluted city in Russia. Indeed, excessive amounts of everything from arsenic to zinc are present in the air, whilst the city and surrounding region is regularly beset with smog and acid rain.

The *'newly industrialised'* emerging markets of Russia, India and China have become the highest polluting countries in the world. Indeed, the spread of heavy industry in Asia's three largest nations has subjected millions of people very high pollution levels ~ reducing human life expectancy in some regions by up to 50%. Across India, for example, the benefits of employment within many industrial cities and towns *(including **'Vapi'**, **'Ranipet'**, and **'Sukinda'**)* are offset by the serious health risks presented by poor working conditions and heavy pollution. Yet vacancies are easy to fill, as the chance to escape poverty has driven millions to look for work in such places.

In China too, the rapid growth of heavy industry has compromised the health of countless numbers of people, with the country home to many of the most polluted cities in the world. At the heart of China's coal mining industry, ***'Linfen'*** in the Shanxi Province, for example, has grown rapidly in order to keep up with the country's insatiable demand for energy. As a result, the surrounding prefecture has suffered from severe environmental damage, whilst poor air quality here affects the lives of over 4 million people. Pollution in China however is widespread, and by no means restricted to waste from fossil fuels or nuclear energy. ***'Tianying'***, for example, *(a small town in the eastern Anhui Province)* is at the centre of Chinese lead production. With the local population exposed to elevated levels of lead in the environment, fatalities caused by lead poisoning are unnaturally high. Meantime, the southern Chinese town of ***'Guiyu'*** in Guangdong Province is home to the largest electronics waste site on Earth. Much of this 'e-waste' is shipped from overseas as a cheaper option than recycling at home, allowing people here to scrape a living from extracting valuable metals from discarded devices. Besides the inevitable leaching of poisons into the soil, the large scale burning of plastic releases all manner of toxins into the atmosphere. Indeed local produce is invariably contaminated with metals such as copper, zinc, and nickel, whilst the proliferation of lead in the environment has caused everything from brain damage to birth defects in a variety of animal species *(including humans)*.

The Chinese industrial boom at the beginning of the 21st century led to environmental degradation on an unprecedented scale. Indeed, currently over ¾ of the world's 25 most polluted cities are in China, with air and water pollution here estimated to kill over a million people every year. The occurrence of dense smog in Beijing and several other Chinese cities, for example, is becoming increasingly common, with cases of lung cancer and cardiovascular disease steadily growing. Particularly heavy and persistent in 2014, photochemical smog is fast becoming a permanent feature of the capital. Moreover, as the Chinese economy grows, 'isolated' industrial accidents are occurring more frequently, and often with greater severity. In 2008, for example, a serious chemical spill turned much of the Han River *(a major tributary of the Yangtze)* red, contaminating drinking water for millions of people throughout Hubei Province for several weeks. Indeed China's comparative lack of environmental concern over the past few decades has led to a rapid deterioration of water quality and land fertility, and now seriously threatens its capacity for continued economic growth.

There is no doubt that the rapid industrialisation of China has caused environmental degradation throughout the country ~ with pollutants contaminating huge areas of land, many river systems and much of the nation's coastal waters. However 'pollution' is not the only destructive by-product of industrial expansion to impact the environment. An inevitable consequence is the eventual exhaustion of natural resources of which drinking water is the most vital. Indeed the scarcity of water has increased dramatically in many parts of China in recent years. Yet in China *(like any other developing country)*, economic growth is considered to be far more important than managed environmental protection.

At the start of the current century, it took around 1000 tons of fresh water to produce one ton of wheat worth about $200. Yet, in monetary terms, when it is appropriated by industry, a ton of water yields approximately seven times as much. As a result China, and many other developing nations, have forsaken the natural regenerative value of fertile land in pursuit of industrial wealth. Yet given its current rate of environmental exploitation, within a few more decades, China will most likely be unable to sustain its own population! Indeed, unless attitudes change dramatically, China will probably experience unprecedented drought, famine and disease, and the resulting weakened economy would, in turn, bring a greater risk of civil unrest, political turmoil and war.

A vastly overpopulated country, China's demise would provide more than just a stark warning for the rest of the industrialised world. At over a trillion **US** dollars, China is the largest foreign holder of American public debt, and serious damage to the Chinese economy would reverberate around the world. Its total collapse would be utterly catastrophic.

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Besides a variety of intergovernmental agencies and departments devoted to monitoring and protecting the environment, there are also numerous environmental organisations that operate independently from political constitution. The largest and best known non-governmental organisations include conservation charities such as the ***'World Wide Fund For Nature'*** *(originating in 1961),* environmental pressure groups such as ***'Greenpeace'*** *(1969)*, scientific research bodies such as the ***'Earthwatch Institute'*** *(1971)*, and ***'Friends Of The Earth'*** ~ an international network of movements founded in 1969. Yet, despite these and numerous other dedicated organisations, environmentalists can do little to stop mankind's incessant exploitation of natural resources and the inevitable degradation of the world around us. Indeed modern *(western)* civilisation has become so reliant on non-renewable *'dirty'* energy, that the mindset of hundreds of millions of 'consumers' would render the prospect of any unfavourable changes to lifestyle *(that worthwhile environmental protection would bring)* as inconceivable.

Carbon dioxide *(CO_2)* is a major constituent of anthropogenic pollution, and most people fortunate enough to live in the developed world require large amounts of energy to maintain their living standards. The subsequent impact on the environment is profound, with vast quantities of $\mathbf{CO_2}$ released in the daily running of societies around the world. Often referred to as a *'carbon footprint'*, the waste produced in the manufacture and distribution of everything from basic necessities to luxury goods is invariably much greater from the day-to-day lives of individuals in North America and Europe, than it is, for example, in South America and Africa. In fact, the environmental cost of contemporary life in the Western World is so high that it would require no less than eight 'Earths' to sustain the human population if everyone on the planet lived this way.

Alas $\mathbf{CO_2}$ levels in the atmosphere continue to increase, as does dangerous particulate pollution such as soot and smoke. Also known as *'black carbon'*, both soot and smoke are the by-products of incomplete combustion of fossil fuels, plants and wood. In some of the most polluted regions of the world, black carbon can cause severe degradation of air quality with disastrous effects on human health. However it can also have a global impact and even affect 'established' weather patterns. Smaller particles can remain in the atmosphere for many weeks, allowing weather systems to take these *(and other industrial pollutants)* far from their site of origin. Aerosols of black carbon have been observed as Arctic haze, with settled particles darkening snow and ice ~ lowering the surface albedo of frozen land and sea. With more sunlight absorbed in these 'less reflective' polar regions, the ongoing warming process is further sped up. Indeed black carbon is twice as effective as $\mathbf{CO_2}$ at raising global surface air temperatures, yet most industrialised nations are reluctant to commit to *'serious'* cuts in carbon emissions.

Throughout civilisation and beyond, the most extensive consequence of human pollution is climate change, and the most apparent feature of this is *'global warming'*. Indeed the first two decades of the 21st century proved to be the warmest in recorded history. By far the greatest long-term threat to civilisation, global warming will inevitably impact both the human world and most remaining wilderness, with abrupt and irreversible changes. It is also a threat to modern civilisation in the shorter-term, with the potential to seriously damage the continued prosperity and security of the even the world's most developed countries. Ultimately the populations of all the world's nations will suffer as climate change reduces essential resources such as food and water. As supplies run low, internal conflict and international wars are inevitable. Indeed it has the potential to bring about the collapse of societies and economies across the globe, and cause the displacement of billions of people on every continent.

During the 20th century, the average global temperature was higher than it had been for at least twelve millennia. At the turn of the new millennium, the **UN**-endorsed ***'Intergovernmental Panel on Climate Change'*** *(IPCC)* predicted that global temperatures would rise by a further 5.8°**C** over the coming century. Put into context ~ even a rise as little as 2°**C** would prove highly disruptive to human life, reducing global agricultural productivity, and causing a widespread loss of biodiversity. Many of the consequences predicted to occur in the wake of a near 6°**C** rise however are abhorrent. Numerous countries, *(probably starting with those in the Middle East)* are likely to be plunged into war as freshwater becomes an increasingly rare commodity. Of course, amongst the first to suffer would be the malnourished populations of many developing nations, with severe crop losses *(including maize and rice)* likely throughout much of South-east Asia, sub-Saharan Africa and Central-South America.

In this warmer world, drought and famine will become increasingly widespread, with tropical diseases such as malaria, dengue fever and schistosomiasis *(as well as various lethal diarrhoeal diseases)* expected to become more widespread across Africa and southern Asia ~ spreading northwards into Europe and North America. In addition, countless species are likely to become extinct simply as a result of rising sea levels consuming low-lying habitats, whist retreating ice caps threaten the existence of a myriad of polar animals. Meantime, vast quantities of carbon dioxide and methane that had previously been locked away beneath the polar ice caps for many thousands of years would be liberated into the atmosphere *(in addition to the ongoing release of greenhouse gasses through everyday human activity)*. Causing long-term disruption to the carbon cycle, global warming on this scale will likely bring about a sudden collapse of the ice sheets that existed long before the first human beings walked the Earth. Indeed climate change over the coming century is going to be critical to the continuance of an unprecedented variety of species, and will fundamentally shape the future of life on Earth.

As a species, human beings are comparatively young and have never experienced the climatic extremes of the distant prehistoric past. With average global temperatures over the last 55 million years having ranged anywhere between 7°**C** and 27°**C**, by human standards today's average of 15°**C** is comparatively comfortable. Our persistent interference with the natural world however, has served to artificially raise the average global temperature, which *(thanks largely to industrialisation)* warmed considerably between the late 18th and early 20th centuries. By the turn of the present century, land temperatures had further risen by almost 1°**C** globally *(with the greatest anomalies occurring in the 1990's)*. At the poles, this rate of warming was even more dramatic, with the temperature rise at the Antarctic Peninsula in the same period, for example, double the global average.

Naturally, there are a whole host of scientific studies around the world into climate change and the present warming trend. Whilst current climate models predict global temperatures at the end of the present century to be anything up to 11°**C** higher than today, it is worth noting that a rise in $\mathbf{CO_2}$ levels similar to today's occurred during an ancient interglacial period 340,000 years ago. On this occasion it led to an average increase of around 6°**C** *(closer to that predicted by the **IPCC** at the turn of the century)*.

The world today is, of course, very different to the prehistoric landscapes of ancient warming periods. For a start there were not 8 billion human beings subtly changing the composition of the ancient atmosphere. One thing is for sure though ~ the warming trend during the current century will not be seamless and gradual, but as different tipping points are reached, dramatic climatic changes will occur. In fact it is widely expected that by 2100, the Earth's climate systems will have undergone a number of sudden 'shifts' as a result of anthropogenic warming. Furthermore it is highly plausible that, given the most likely projected temperature rises, a number of systems which influence the planet's weather patterns actually risk complete collapse in the very near future. Indeed it is possible *(or in some instances, very likely)* that sometime before 2050 we will experience, for example, the collapse of the West African and Indian summer monsoons, irreversible dieback of the Amazon and Boreal forests, the melting of all Arctic summer sea-ice, and the collapse of the Atlantic thermohaline circulation ~ all of which would have a profound effect on global weather patterns.

There is little doubt that the present warming trend is predominantly caused by human activity; i.e. it is anthropogenic in nature. Indeed, the growing atmospheric saturation of $\mathbf{CO_2}$, a primary greenhouse gas, is largely down to the vast quantities produced by the persistent combustion of fossil fuels *(namely coal, petroleum oil and natural gas)* around the world. Having been comparatively steady for several millennia, background levels of atmospheric $\mathbf{CO_2}$ have risen markedly since the start of the industrial age when the widespread burning of coal began in earnest ~ kick-starting a gradual rise in global temperatures that continues to this day. In the subsequent 250 years or so, we have released over 500 billion tonnes of carbon into the atmosphere.

Having reached 0.04% by volume in 2012, **CO_2**, as a greenhouse gas, is second only in abundance to water vapour *(at roughly 0.25% of the atmosphere by mass)* which is mostly concentrated in the tropics. Throughout prehistory, volcanic activity has been a primary source of both atmospheric **CO_2** and water vapour, often making it the major cause of past periods of global warming. During the 20th century however, atmospheric **CO_2** produced by volcanoes accounted for less than 1% of the amount released through human activity. Indeed the present warming trend cannot be explained by natural processes alone.

At the turn of the 21st century, around 30 gigatons of **CO_2** was being released into the atmosphere annually just by burning fossil fuels. Growing at a year-on-year rate of about 2.5%, by 2010 this figure had risen by a further 8 billion tons. Yet human activity is by no means greatest contributor to atmospheric **CO_2**. A vast majority *(some 95%)* is released through the natural process of decay. But we inherited a world in balance, with virtually all excess **CO_2** produced by decomposition being taken up by the trees and the oceans. However our purposeful destruction of rainforests and inadvertent disruption of oceanic currents has weakened these two natural 'carbon sinks', allowing atmospheric **CO_2** to build up ever faster. Indeed the widespread clearance of forests *(over 40% of the world's rainforests, for example, have disappeared since the mid-19th century)* amounts to another major anthropogenic cause of global warming.

When you consider that what remains of the world's rainforests currently contribute around 30% of the planet's freshwater supplies, our blind disregard for the natural world and interference with systems that regulate the biosphere is profound. For example, the systematic destruction of the Amazon rainforest *(largely by 'slash and burn' clearance)* has resulted in over 325,000 square miles of forest canopy being lost since the 1970's ~ largely to exploit the fertile soil beneath it. However as the forest canopy shrinks, so the risk of drought here increases.

Another, particularly devastating, example of our short-sighted exploitation of the environment has occurred on Indonesian Borneo, where thousands of square miles of peat swamp forests have been drained since the 1990's in order to convert it to agricultural land. This, along with illegal logging and other unregulated clearance of the Borneo forests, has also led to uncontrolled fires that amount to an ecological disaster of global proportions. Not only does the dried swamp land relinquish sulphurous compounds that pollute local river systems, but phenomenal amounts of carbon stored over several millennia are liberated ~ with far reaching consequences. Releasing up to 3.5 billion tonnes of carbon into the atmosphere each year, the extensive destruction of the Borneo peat swamp forests amounts to the largest single human contribution towards rising concentrations of atmospheric **CO_2**.

One of the most immediate effects of rising temperatures is the gradual disappearance of vital freshwater supplies. Indeed most of the world's major rivers have declined significantly since the mid-20th century. From the ***'Colorado'*** and ***'Amazon'*** in the Americas, to the ***'Ganges'*** and ***'Yellow River'*** in Asia ~ all have seen a reduction in water flow due to both climate change and direct human activity. In addition, the poles are shrinking as the Arctic waters warm, whilst the 'climatic snow-lines' along the world's mountain ranges continue to rise in altitude.

During the first decade of present century, average glacial retreat was around 5ft. *(1.5m)* annually ~ a rate that continues to rise. Just as glaciers reduce in length, so they shrink in thickness at a similar rate. Having lost over 80% of its glacial ice over the last century, the shrinking ice-cap of ***'Kilimanjaro'*** in Central Africa, for example, is actually set to disappear sometime in the mid-2020's. Helping to nourish the enormous ecosystems of the ***'Serengeti'*** and ***'Maasi Mara'***, the glacial waters of Africa's highest mountain are hugely important to many indigenous species.

Meantime glaciers across the world are largely retreating. Those in the tropical Andes, for example, shrunk by up to 50% between 1970 and 2001, whilst most Alpine glaciers are expected to diminish by about 75% during the present century. By the 1990's approximately 95% of all glaciers in the Himalayas were in an accelerated retreat, and could potentially lose over 80% of their mass by 2100. The drainage basins of the Himalayan rivers *(including the Ganges, Indus, Yangtze, Mekong and Yellow rivers)* sustain a collective population of around 2.5 billion people. As warming continues and the glaciers retreat, over time these rivers are likely to be severely weakened when important tributaries begin to dry up ~ depriving many established communities of freshwater. Yet besides degrading these mighty rivers, the continued retreat of Himalayan glaciers also increases the risk of flash flooding. As new glacial lakes become swollen with meltwater, the moraine that contains them can be dramatically breached, posing enormous danger to human settlements down-river.

Whilst climates are warming across the planet, over the last century temperatures in the Arctic region increased at almost twice the average global rate. Boosted by the phenomenon of polar amplification, radiant energy in the Arctic Ocean has served to intensify the current warming trend. Indeed the annual rate of ice loss here rose six-fold between the 1990's and 2000's, and by 2022 the acceleration of Arctic warming had increased considerably ~ taking it to over four times the global average.

Alas the dramatic loss of Arctic ice has also allowed human activity to encroach further into this frozen environment. By 2007, for example, the most direct shipping route from Europe to Asia and the American west coast *(the **'Northwest Passage'**)* became ice free and fully navigable for the first time in recorded history. This new 'economic link' between the Atlantic and Pacific oceans *(along with the prospect of vast mineral deposits being revealed by the retreating ice)* sows the seeds for many international disputes.

With the winter recovery of sea ice no longer as robust as it once was, the complete disappearance of frozen seawater in the Arctic Circle during the summer months could occur as soon as the late 2020's. It is known that sea ice reflects approximately 80% of the sunlight that strikes it, whilst the open ocean absorbs some 90%. As a result, the more ice that disappears in the Arctic, the warmer average temperatures here become, creating a positive feedback loop. As the open waters of an *'unfrozen'* Arctic Ocean absorb more solar energy, so the warming here is accelerated, causing ice cover in the Arctic summer to shrink even faster. Indeed perennial ice cover has reduced enormously since 1980 and continues to diminish, with sudden drastic losses sporadically occurring. In the summer of 2005 for example, sea ice cover shrunk by a whopping 14% *(compared to an average loss of 7% per decade previously).* Furthermore, the loss of Arctic ice compounds the effects of greenhouse gas emissions.

Within the first three decades of the 21st century, summer ice across the entire Arctic circle *(including glaciers, ice caps, sea ice and tundra)* is expected to diminish by up to 75% in volume. Even the vast ***'Greenland ice sheet'*** is shrinking at an alarming rate ~ its height falling at just over 3ft. *(roughly a metre)* a year, as it gradually loses mass. Indeed 20% more ice is lost from basal melt, runoff and iceberg production, than is gained from fresh accumulations of snow each year. By the turn of the present century the great Greenland ice sheet was losing over 50 cubic miles of ice annually; with an equivalent mass of around 200 gigatonnes. The glaciers around its edge continue to retreat as they flow inexorably towards the ocean. Meantime the vast ice shelves around much of Greenland's coast are no longer undergoing annular regeneration, and are also shrinking rapidly every summer. It is staggering to think that there is so much frozen water locked up in Greenland that, were it to melt completely, it would contribute a 22ft. *(7m)* rise in sea level around the globe.

On the other side of the world, lies Antarctica where over 70% of the planet's freshwater is stored. On the Antarctic Peninsula, a vast majority of glaciers are not only in rapid retreat, but are flowing significantly faster. Indeed between 1993 and 2003 most glaciers here sped up by some 12%.

Of similar size and volume to the Greenland ice sheet, the ***'West Antarctic ice sheet'*** is also thinning at an unprecedented rate. Not only is the bedrock on which the ice sheet rests below sea level *(making it more susceptible to the warming ocean around it)*, but it partially sits over a volcanically active region which further undermines its integrity. Moreover, by 2010, western Antarctica was found to be warming at almost 0.2°**C** per decade ~ much faster than the global average. As a result, it is home to some of the fastest moving glaciers in the world. In 2008, for example, the ***'Pine Island Glacier'*** was found to be moving at over 2 miles *(3.5km)* a year and dumping around 46 gigatonnes of freshwater into the ocean annually. At 18½ miles *(30km)* wide and 1¼ mile *(2km)* thick, this enormous glacier was also discovered to be accelerating by an astonishing 7% each year ~ and it was not as a direct result of rising local temperatures. In fact, the effects of climate change on the surrounding seas caused the re-channelling of deep ocean currents that now bring warmer waters to the mouth of the glacier ~ undercutting the ice stream and lubricating its flow.

Elsewhere on Antarctica, is the far larger ***'East Antarctic ice sheet'***, which contains 90% of the continent's 6 million cubic miles *(25 million km^3)* of frozen freshwater. However unlike the Greenland and West Antarctic ice sheets, the massive East Antarctic ice sheet has conversely started to bulge at its centre. Here, warmer air has led to greater evaporation and precipitation ~ with increased snowfall adding to the central mass of the world's largest ice sheet. Unfortunately this doesn't compensate for the vast amounts of ice lost to the warming Southern Ocean that surrounds it. Around 90% of the ice sheet's glaciers are currently in retreat, and the increasingly regular collapse of colossal ice shelves around its perimeter causes an overall decrease in its mass. Indeed as these ice shelves weaken, break away and disappear, so the glaciers behind them naturally speed up, reducing the overall volume of the East Antarctic ice sheet.

By the end of the present century, sea level rise is expected to be considerable as a result of ice melt and thermal expansion *(as well as changes to many established ocean currents)*. Even the most conservative estimates predict absolute sea level to have risen anywhere between 7 inches *(18cm)* and 2ft. *(around 60cm)* by 2100, with some models projecting rises of anything up to 6½ ft. *(about 2m)*. It is clear that many major cities, including ***'London'***, ***'New York'*** and ***'Singapore'***, will struggle to maintain effective sea defences, whilst many low-lying island states such as ***'Tuvalu'***, the ***'Maldives'*** and ***'The Marshall Islands'*** could disappear altogether. In addition, many countries with highly populated coastal regions, including ***'China'***, ***'Egypt'*** and ***'Bangladesh'*** are likely to suffer huge displacement of their peoples. A developing nation and one of the most densely populated regions of the world, over 80% of Bangladesh, for example, already lies within a metre of sea level.

Over the coming decades, there are likely to be hundreds of millions of climate refugees around the world, and human conflict is inevitable, as living space and freshwater become premium. To compound matters, the pace of climate change is actually accelerating. Yet, even if the ongoing warming trend were to continue at its present rate, the entire Antarctic continent would be completely free of ice within just three centuries. By then absolute sea level would have risen by a further 230ft. *(70 metres)*. However soon it occurs, it is clear that the current warming process is leading towards this end, with disappearing ice cover allowing more and more of the Sun's energy to be absorbed by the open seas, serving to warm the planet further and perpetuate a strengthening feedback mechanism.

The importance of the Southern Ocean's state of health cannot be understated. For the past 30 million years it has acted as a huge carbon sink ~ contributing to approximately 15% of our planet's natural ability to absorb atmospheric $\mathbf{CO_2}$. However, in 2007 its steady rate of absorption was observed to falter. With warmer seas absorbing less atmospheric $\mathbf{CO_2}$ *(the solubility of* $\mathbf{CO_2}$ *decreases by around 4% for every 1°C rise in water temperature)*, the Southern Ocean is particularly vulnerable to climate change. Not only is its ability to store $\mathbf{CO_2}$ diminished by penetrating warm water currents from the tropics, but it is also susceptible to the effects of ozone depletion in the upper atmosphere. Indeed the annual ozone hole that appears over Antarctica has a profound effect on atmospheric circulation, creating stronger winds that whip up the Southern Ocean and causing photic water to be saturated with $\mathbf{CO_2}$. As a result, its ability to absorb at lower depths is diminished, reducing its overall effectiveness as a carbon sink. When you consider that $\mathbf{CO_2}$ emissions from human sources are markedly rising, then it is little wonder that concentrations of atmospheric $\mathbf{CO_2}$ are also rising.

When ancient ice melts, greenhouse gasses *(largely carbon dioxide and methane)* that have been locked up for millennia are liberated into the atmosphere. Equally pertinent however, is the release of more water vapour ~ the most significant contributor to local warming. Furthermore, when perennial sea ice finally disappears *(as is happening in the Arctic circle)*, the darker ocean waters are exposed to sunlight and the water now absorbs, rather than reflects, most solar energy which naturally causes the region to warm still faster. The occurrence of a *'positive feedback loop'* created by the disappearance of sea ice can be regarded as a pivotal *'tipping point'* towards irreversible warming.

Yet there are many positive feedback loops and tipping points that are likely to be reached as the planet continues to warm. Another example has become apparent over much of the north-eastern Pacific where low-level cloud cover *(mist and fog)* has been dramatically reduced by the warming ocean waters. Once a regular occurrence, rising temperatures have subtly altered prevailing weather conditions here, causing fog to form less frequently. Whereas water vapour in the atmosphere has a warming effect *(particularly in the tropics)*, low-level cloud cover at more northerly latitudes has a cooling effect, and without it sunlight warms the surface water further.

The many adverse effects of anthropogenic climate change on the biosphere are likely to be profound, with most plant and animal species invariably suffering as a consequence. One of the starkest of tipping points that could potentially occur over the coming century would happen when the world's remaining forests switch from net absorbers to net producers of $\mathbf{CO_2}$. This would occur when their already diminishing ability to soak up 'anthropogenic carbon' in the atmosphere is offset by the release of carbon locked up within trees that had now been cleared.

In 2004 it was realised that the Amazon *'carbon sink effect'* was slowing considerably. Whilst trees in the deepest parts of the Amazon remained comparatively healthy, they continued to suffer at its peripheries, with forest die-back, drought, wildfires, and purposeful deforestation all reducing the size of this great rainforest. Not only does a smaller forest have a reduced capacity to absorb $\mathbf{CO_2}$ from the atmosphere, but excessive amounts of anthropogenic $\mathbf{CO_2}$ have effectively served to fertilise the Amazon rainforest ~ speeding up the life cycles of many species. Even in pristine areas of forest, many plants were observed to be growing and dying at a faster rate, causing emergent trees to produce wood of less density ~ drastically lowering carbon storage within the canopy. Moreover, this higher mortality rate and greater loss of *'old growth'* trees can be seen in forests around the world. Indeed a higher proportion of dead and decaying trees releases even more carbon into the atmosphere, whilst the subtle but widespread hydrological changes that occur as a result could even impact established weather patterns.

As far as the world's flora is concerned ~ it is not just forest biomes that are intimately connected with climate change and its effects. Whilst excess $\mathbf{CO_2}$ in the atmosphere has caused the life cycles of many forest trees to speed up, conversely warmer, drier climates can slow the growth and inhibit the development of established plants. This also compromises their effectiveness at storing carbon, and it has been found that the ability of grassland, for example, to take up $\mathbf{CO_2}$ is greatly reduced with rising temperatures. By tightening the apertures of their stomata, grasses *(like most advanced plants)* can conserve water during warm dry periods. Although this mechanism enables them to survive extremes, it stifles their ability to perform photosynthesis, and when they do not grow, less carbon is stored in the soil than is emitted as $\mathbf{CO_2}$ through microbial respiration and decomposition. Indeed a European heatwave in the summer of 2003 actually turned the continent's grasslands from a net absorber of $\mathbf{CO_2}$ into a net producer.

Another profound change brought on by warming temperatures has occurred in the chemical signals of flowering plants. The fragrant chemicals emitted by angiosperms are known as *'biogenic volatile organic compounds' (or 'BVOC's)*, and their production increases as temperatures rise. As a result, the reaction of **BVOC**s to climate change can actually alter the physiological and ecological functions of a myriad of plant species. When you also consider the subtle influences of increased ozone pollution, higher concentrations of atmospheric $\mathbf{CO_2}$, and raised levels of **UV** radiation, then the excessive production of **BVOC**s can have a significant effect on plant communication and reproduction. Moreover, even the slightest disruption to these essential airborne signals can readily confuse bees and other vital pollinators.

The discernible human influence on current warming trends and its many consequences cannot legitimately be questioned. Neither can the link between rising temperatures and changes to plant and animal behaviour. Indeed over the past few decades, numerous observational studies have catalogued the habits of a huge variety of plant and animal species and their reaction to current climate changes. One of the earliest facts to be proven was that a warming climate causes the ranges of most migratory species *(including insects, arachnids, birds and mammals)* to naturally shift to higher latitudes and elevations in order to survive.

The current warming trend affects ecosystems at every latitude and at every altitude ~ be they evergreen forests, mangrove swamps or coral reefs. For many, the effects of global warming *(direct or otherwise)* can bring about a gradual deterioration and eventual destruction of numerous different habitats, and the number animal species threatened by climate change is simply huge. Examples are as diverse as the polar bear *(whose dwindling population in the Arctic north continues to suffer from a loss of sea ice on which to hunt)*, and the golden toad *(whose outright extinction from the high altitude forests of Costa Rica was caused by hot dry conditions and the spread of chytrid fungus)*. However, between the distant realms of polar bears and tropical toads are vast regions of land where a temperate climate predominates. Here global warming is effectively shifting the seasons, with springtime gradually moving further forward every decade. Indeed by the turn of the 21st century, spring was starting around one week earlier than it had in the 1970's, whilst onset of autumn was delayed by about three days. In geological terms, these changes are happening extremely fast, and many plants and animals are already struggling to adapt, with interdependent species reacting in different ways and at different rates to the shifting seasons. As warming continues, it puts enormous stress on the food web, and should the entwined habits of different species not remain synchronised, many wild animal populations will inevitably collapse.

The environmental disruption that ongoing climate change will bring over the forthcoming decades and centuries is incredibly profound, and the consequences for humanity are many. The current global warming trend benefits aphids, for example, whose numbers have grown dramatically over recent years. These highly adaptable insects can cause serious crop damage, and their eggs *(along with those of a number of other agricultural pests)* are not only more likely to survive milder winters, but now hatch earlier in the year with the onset of spring.

Whilst agriculture and many other human endeavours are likely to suffer greatly as a result of climate change over the coming years, the environmental damage it will cause is unimaginably huge, with various 'natural systems' across every continent already showing signs of stress. Throughout the first half of the 21st century, the frequency of extreme drought conditions, for example, is expected to rise fivefold ~ destroying many [once] fertile regions of land. Indeed, by 2050 climate change is likely to have rendered a further 10% of the world's land area uninhabitable to numerous plant and animal species.

With global weather patterns slowly shifting, many already dry regions are being turned to parched desert, and water supplies are close to exhaustion in some countries. As atmospheric carbon levels continue to rise, so dryer regions of southern Europe, and North America, for example, will experience even less rainfall, whilst vast swathes of Africa and Australia are likely become even more inhospitable to indigenous life. Moreover, with extreme weather conditions becoming increasingly commonplace, other fertile regions will be lost to flood, whilst large areas of coastal land across the world will have become submerged beneath the rising seas. Alas global warming is subjecting numerous terrestrial habitats to enormous pressure, and the number of species likely to be driven to extinction during the 21st century could run into millions.

Most animal species that succumb to climate change over the coming century however will be lost as a consequence of ocean warming. Indeed warmer waters are already beginning to stifle nutrient enrichment in the Arctic and Southern Oceans as 'upwelling zones' are fundamentally altered. Critical to the aquatic food web, a loss of nutrient-rich waters here would greatly diminish phytoplankton numbers, and has the potential to wipe out thousands of dependant species at a stroke. Phytoplankton are relied upon by almost all oceanic animals *(and most freshwater creatures)*, and were they unable to bloom, it would undoubtedly bring general starvation to the world's oceans and seas. A scientific paper in 2010 ostensibly suggested that phytoplankton numbers had been reduced by 40% since 1950, and that the decline continues at a rate of approximately 1% a year. Whilst the accuracy of this report was questionable, what is not in doubt is that global warming will bring disruption to oceanic currents, reduce plankton numbers and devastate the established feeding grounds of numerous marine species. Furthermore, the action of photosynthesis by phytoplankton currently produces vast quantities of oxygen and removes CO_2 from the air. In fact, so numerous and important are these tiny organisms, that they are second only to the tropical rainforests in reducing the effects of anthropogenic CO_2 emissions.

The most common agents of primary production in the food web, phytoplankton ultimately sustain nearly all complex marine life in the world's oceans and seas. Indeed the health of autotrophic plankton *(such as diatoms, cyanobacteria and dinoflagellates)* is inextricably linked to the health of the oceans themselves. Alas, the gradual warming and increasing acidity of the oceans not only undermines numerous marine ecosystems, but it threatens to disrupt the balance between deep-water bacteria and many types of phytoplankton ~ causing oxygen levels to plunge in the photic zone. In a worst case scenario, it could cause massive emissions of hydrogen sulphide to belch from the world's oceans, which would poison the atmosphere and kill numerous terrestrial plants and animals too. It even has the potential to decimate the ozone layer; exposing any surviving species to extreme levels of ultraviolet radiation. Whilst this vision may seem far-fetched, such a deadly scenario resulting from oceanic warming has occurred at least twice in Earth's long prehistory.

With our planet undergoing a process of dramatic global warming, we experience an ever-greater number of natural disasters every decade. Indeed the unprecedented speed at which climate change is occurring has served to intensify weather systems and make extreme meteorological phenomena more common. The amount of Atlantic hurricanes, for example, doubled over the course of the last century, whilst the number of serious floods has increased six-fold since the 1980's. In terms of economic impact, in 2005 annual global losses from natural disasters passed the **$**200 billion mark for the first time, with the financial costs in subsequent years continuing a sharp upward trend. By 2021 that figure had surpassed **$**270 million, and the annual cost of climate change was now projected to exceed **$**2 trillion by the end of the century in the **US** alone!

As warming continues and weather patterns shift, severe droughts *(like cyclones and hurricanes)* have also become more commonplace. In 2005, for example, a devastating drought in the lush Amazon basin was primarily caused by the 'sudden' warming of waters in the tropical North Atlantic ~ shifting weather systems and diverting the rains. Droughts of this severity in the Amazon were believed to occur around once a century. However, as unusually severe as this drought was, it was surpassed just five years later with another, even bigger drought in 2010 that encompassed an area some 1.2 million square miles *(about 3million sq. km)*. What is particularly stark about these events is their impact on CO_2 accumulations in the atmosphere. Throughout the 1990's and early 2000's, the Amazon basin was absorbing an average of 1.5 billion tonnes of atmospheric CO_2 every year. However some 13 billion tonnes of the greenhouse gas *(equivalent to the annual emissions of China and the **USA** combined)* were released as a direct result of these droughts. Alas it appears that the Amazon rainforest is rapidly heading towards a tipping point, beyond which irreversible dieback could completely destroy its integrity.

Another important factor in the frequency of extreme weather phenomena is the ***Atlantic Multidecadal Oscillation (AMO)*** ~ a defined pattern of sea surface temperature changes in the North Atlantic Ocean which can have a profound effect on the weather of four continental land masses. Related to subtle changes in both the thermohaline circulation and established wind patterns, the **AMO** index represents a series of warmer and cooler phases in sea surface temperature, with peaks and troughs often spanning several decades. Warm phases of the **AMO** are associated with drought in many parts of North America, but conversely with heavier rains in the Indian subcontinent. It is also linked to the activity *(and severity)* of Atlantic hurricanes, whilst cool phases coincide with the failure of monsoon rains and severe droughts in West Africa that can last for decades. Moreover, depending on its phase, the **AMO** alternatively masks or exaggerates the effects of anthropogenic warming. When the two 'conspire' the likelihood of a *'mega-drought' (that could last a century or more)* is significantly increased. Although many such droughts have occurred in prehistory, modern civilisation is yet to be challenged by one so severe.

Not only are droughts becoming increasingly common in tropical, subtropical and temperate latitudes, but global weather patterns as a whole are becoming more erratic and extreme. Generally speaking, as temperatures increase, so does the rate of evaporation, and a warmer atmosphere with a greater capacity to absorb water naturally generates more energy to dissipate. Indeed global warming increases the destructive power of cyclones, hurricanes and tornadoes, as well as the intensity of El Niño conditions. It can even alter the frequency of major earthquakes, with atmospheric changes having a subtle influence on geological ones. The redistribution of ice mass over fault lines and hotspots, and the release of vast quantities of freshwater into subterranean vents are just two examples of how climate change can influence geological activity.

In the first decade of the 21st century, sea surface temperatures across the globe rose by almost 1°**C** more than the long term average *(as recorded over the previous century)*. As a result, the general size and intensity of prevailing weather systems continued to grow and, with extreme weather becoming more frequent, human civilisation has inevitably had to deal with an ever greater number of natural disasters. But warmer waters don't just power more intense storms, they bring an almost immeasurable number of consequences for life in the oceans. Indeed the warming of the world's oceans and waterways has an enormous impact on the health of the planet as a whole, and nowhere is this more evident than throughout the delicate natural biomes that grace Earth's northernmost latitudes.

In 2004, Alaska, for example, experienced an unusually hot, dry summer, during which time it suffered what was the state's largest single wildfire in recorded history. Indeed the ***'Taylor Complex Fire'***, as it became known, was just one of over 700 Alaskan fires *(covering a combined area of over 10,400 square miles [27,000 km^2])* to have burned out of control during this year. Put into context the '2004 Alaska fire season' released around 2 million tonnes of carbon into the atmosphere ~ or about as much as the entire Arctic tundra absorbs in a year. With the number of seasonal wildfires continually increasing throughout North America, by 2020, no less than eight devastating fires of greater size and destruction than the 'Taylor Complex Fire' had destroyed vast swathes of California *(in 2008 and 2020),* Texas *(in 2011)*, Northwest Territories *(in 2014)* and British Colombia *(in 2017 and 2018)*.

Another, more direct, consequence of warming northern oceans is the increased production of icebergs which readily calve from shrinking glaciers and ice shelves. With an increasing abundance of freshwater being dumped into the Arctic Ocean, the decreasing salinity of high latitude waters has the potential to bring about dramatic changes to North Atlantic currents, which would have profound implications for many marine ecosystems. Moreover it could even impact upon the thermohaline circulation ~ a vital regulator of the global climate.

Thermohaline circulation *(also called the 'ocean conveyor belt')* is a pan-oceanic network of currents that are primarily driven by density gradients of temperature and salinity. An integral part of this process is the ***'Atlantic Meridional Overturning Circulation' (AMOC)*** which comprises a number of powerful currents that continually mix the waters of the Atlantic Ocean ~ transporting heat, nutrients, oxygen and other dissolved gasses across the globe. Here warm, largely wind-driven, surface currents become increasingly saline as they flow northward from the tropics. As evaporation and cooling increase the density of the water, it sinks, forming deepwater masses in the North Atlantic Ocean and Arctic Sea. These slowly move southwards, becoming increasingly diffuse as they warm and mix with water masses of different densities, Much however eventually wells up in the Southern Ocean, only to flow northwards again, providing the Atlantic ocean with a continuous conveyor belt of *fresh* seawater.

Fed by the ***'Gulf Stream'*** *(a wind-driven current that transports warm Caribbean waters to the North Atlantic)*, the most northerly 'branch' of the **AMOC** is known as the ***'North Atlantic Drift'*** ~ a warm surface current that is drawn north-eastwards by the sinking deep water masses in the far north. This has a considerable warming influence on the climate of northwestern Europe. However, global warming *(in particular the increasing temperatures of photic water)* is weakening the whole process of thermohaline circulation, and threatens to dramatically shift the entire global climate. An increased rate of evaporation over the North Atlantic Ocean and larger freshwater fluxes in polar waters weakens the process, and could even trigger its complete collapse. Between 1980 and 2005 overturning circulation across the Atlantic Ocean had already decreased by around 10%, and by 2050 the Gulf Stream itself is expected to have decreased in size by a further 20%. Without the warm surface waters of the North Atlantic Drift, regions such as the British Isles, Iceland and Scandinavia would experience much colder winters than they presently do.

Were the North Atlantic Drift and/or Gulf stream to shut down completely, it would temporarily *(but suddenly)* reverse the effects of global warming across northwestern Europe ~ fundamentally altering weather patterns throughout the northern hemisphere. Indeed the subsequent collapse of the **AMOC** wouldn't just provide a temporary 'rest bite' from the incessant warming of climate change, but it would lead to abrupt temperature shifts across much of the planet. Similar 'shutdown events' occurred during the last glacial period, causing rapid climate fluctuations and temperature drops of up to 10°C to occur within the space of a decade. Should such an event happen today it would have profound implications for both human civilisation and life as a whole. It is likely to increase the frequency and intensity of El Niño events, whilst the demise of established seasonal weather patterns would bring flood and drought, causing widespread crop failure, starvation and disease. Furthermore, without an effective system to circulate nutrients and oxygen across the North Atlantic, the collapse of established plankton stocks is also highly probable. Not only would this bring mass starvation to most marine life, but, in a worst case scenario, it could even cause vast areas of the Atlantic to stagnate ~ leading to an oceanic anoxic event.

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A *'greenhouse gas'* is an atmospheric gas that absorbs and emits radiation in the thermal infrared range. Without natural greenhouse gasses in the atmosphere, it is estimated that the average global temperature would be around -20°C. However their overabundance in the atmosphere is the single greatest reason for climate change today.

By far the most significant greenhouse gas is ***'water vapour'*** *(H_2O)*, whose presence in the atmosphere can vary considerably. Whilst the atmospheric saturation of water vapour can reach up to 5% in humid conditions, it can be negligible in extreme arid regions of the world. Yet, despite averaging just 0.4% by volume globally, atmospheric water vapour enables the process of condensation to occur. This supplies latent heat to the atmosphere, which leads to the formation of clouds and effectively drives the planet's weather. Indeed, the condensation of water droplets substantially increases atmospheric energy *(which is released during precipitation)*. With suspended molecules of $\mathbf{H_2O}$ strongly absorbing the infrared region of the light spectrum, water vapour contributes to anywhere between 35-70% of the overall greenhouse effect.

Although it is only a trace gas within the atmosphere, the second most abundant greenhouse gas is ***'carbon dioxide'*** *(CO_2)*. Like water vapour, $\mathbf{CO_2}$ molecules are transparent to visible light, but they strongly absorb light in the infrared and near-infrared, before slowly re-emitting the energy. Concentrations of $\mathbf{CO_2}$ also fluctuate seasonally *(and are associated with the northern hemisphere growing season)*. Unlike water vapour however *(which has an atmospheric lifetime of around 9 days)* $\mathbf{CO_2}$ molecules can remain in the atmosphere in a free state for up to a century. As a result, it currently contributes around 26% of the current warming trend.

When the Miocene epoch began, some 23 million years ago, atmospheric $\mathbf{CO_2}$ concentrations stood, like today, in the region of 0.04% of the atmosphere *(or 400ppm [parts-per-million] by volume)*. Concentrations back then remained relatively high, largely due to prolonged volcanic activity in North America at this time. Indeed they did not start to decline until around 10 million years later, when the planet cooled enough to eventually form the polar ice caps that exist today. From then, right up until the late 18th century, concentrations of atmospheric $\mathbf{CO_2}$ fluctuated between 180-280ppm in a cycle of numerous glacial and interglacial periods.

In the final decades of the 'pre-industrial' age, atmospheric $\mathbf{CO_2}$ concentrations stood at approximately 270ppm. Although readings vary slightly with the seasons, at the turn of the current century, concentrations were approaching 380ppm, and by 2015 the psychological threshold of 400ppm was finally reached. Alas this happened to be the level that most climatologists agreed was essential to avoid if the international target of keeping warming over the coming century to below 2°C was to have any realistic chance of being met.

Yet, greenhouse gas emissions from developing Asian economies is expected to quadruple over the first three decades of the 21st century. Indeed concentrations of greenhouse gasses in the atmosphere continue to break records ~ reaching new highs on an almost annual basis. To put today's rises into perspective; right up until the mid-19th century, it had taken around 100,000 years for $\mathbf{CO_2}$ levels in the atmosphere to increase by about 1.5ppm by volume, but by the start of the 21st century, a rise of this magnitude was occurring, on average, every year. Moreover, $\mathbf{CO_2}$ concentrations continue to increase ever more rapidly, with levels rising 2.3ppm between 2009 and 2010 alone. During the same period, concentrations of other atmospheric pollutants such as ***'nitrous oxide'*** *(N_2O)* and ***'sulphur dioxide'*** *(SO_2)* rose with equal acuteness.

With atmospheric $\mathbf{CO_2}$ concentrations continuing to rise at an alarming rate, measurements at the '***Mauna Loa Observatory'*** in Hawaii exceeded 420ppm by the early 2020s. Indeed, between 2001-2050 anthropological $\mathbf{CO_2}$ emissions are anticipated to rise by a staggering 140%, and by the end of the century, levels are very likely to have surpassed 1,000ppm. In fact atmospheric concentrations of $\mathbf{CO_2}$, nitrous oxide, and ***'methane'*** *(CH_4)* are currently the highest they have been for at least 650,000 years. The warming effect that these, and other, greenhouse gasses are having on the global climate is substantial, with the rate of melting ice currently contributing to a sea level rise of just over a tenth of an inch *(around 3mm.)* annually.

Few places feel the effects of climate change more acutely than Siberia, where average summer temperatures have increased by almost 3°C over the last four decades. One of fastest warming regions on Earth, the lowland plains of Western Siberia is home to the world's largest frozen peat bog. Having been in a state of frozen suspension for around 11,000 years, vast areas of swampland here have begun to thaw, and the shrinking permafrost has the potential to release billions of tons of methane trapped beneath it. The growing amount of methane escaping from beneath the frozen lakes and swamps of Western Siberia is perhaps the most evident example of a *'positive feedback loop'* caused by the current warming trend. The release of subterranean methane into the atmosphere is hastened by rising temperatures, which are in turn caused by greenhouse gasses, of which methane is amongst the most potent.

After water vapour and carbon dioxide, methane is presently the third largest contributor to global warming. Whilst much is produced naturally, over half of the

590 million tons of methane created every year comes from human activity *(notably farming, as well as from landfills, mining and waste treatment)*. At around 12 years, the atmospheric lifetime of methane is much shorter than $\mathbf{CO_2}$ but, as a greenhouse gas, it is approximately 33 times more potent. Not only does atmospheric methane largely break down into $\mathbf{CO_2}$ and water vapour but, under certain conditions, its oxidation can produce ***'ozone' (O_3)*** ~ yet another potent greenhouse gas.

Concentrations of atmospheric methane have increased by around 150% since the start of the 'Industrial Age' in the mid-18th century, reaching 1800 parts-per-billion in 2011 ~ far higher than it has been for well over ½ million years. Moreover, methane levels are actually greater in the northern hemisphere where both human and natural sources are concentrated. Atmospheric methane currently contributes up to 10% of the greenhouse effect, but as the planet warms, so more and more is produced, and this is particularly evident at high northerly latitudes. Indeed, in the vast wetland areas that surround the Arctic Circle, methane levels continue to rise, not only due directly to additional anthropogenic emissions, but also indirectly ~ through the natural consequences of anthropogenic warming.

As the ice retreats, so the fermentation of organic matter increases, with trillions of micro-organisms producing methane directly from the 'living biomass'. Known as *'methanogenesis'*, this natural production of methane occurs as a metabolic by-product in anoxic conditions. However with many sub-polar climates experiencing increasingly warmer and wetter summers, the advancing vegetation in Boreal landscapes sustains growing numbers of methanogenic archaea and bacteria. In addition to enhancing methanogenesis, the warming of northern latitudes reduces Arctic ice cover ~ allowing the oceans to warm further, which can enable methane that has been trapped beneath the sea for many millennia to escape into the atmosphere. This release of ancient methane deposits *(that have been stored as frozen 'clathrates' for tens of thousands of years)* is most evident along the margins of ice cover around Greenland and Alaska. By 2012 over 150,000 methane 'seeps' had been identified, and the number continues to increase ~ with sudden and dramatic releases of subterranean methane deposits only serving to further exacerbate the ongoing warming process.

The largest deposits of methane clathrates lie on the deep ocean floor, as well as along several continental shelves in the Arctic region, where their cohesion is particularly susceptible to a rise in water temperature *(or a drop in water pressure)*. Should they break up en-masse, these clathrates have the potential to release many billions of tons of methane into the atmosphere. Indeed, at around 7 trillion tons, there is believed to be far more methane locked up as frozen hydrates beneath the oceans than there is remaining reserves of natural gas. When you add in the massive 'terrestrial' clathrate stores under the Arctic permafrost, then it is clear that the escape of such quantities of methane into the atmosphere has the potential to catalyse runaway global warming. Known as the ***'Clathrate gun hypothesis'***, this sudden and irreversible release of more and more frozen methane into the atmosphere presents another potentially calamitous 'tipping point' for modern climate change. Methane clathrate breakdown has occurred on several occasions in Earth's long prehistory, and is believed to have completely changed the ocean environment when it happened during the Permian extinction event some 251 million years ago. More pertinently, it could cause abrupt warming in the not too distant future.

At the turn of the 21st century it was realised that a rise in deep sea temperature of just 5°**C** would be sufficient to sublimate enough solid methane hydrate *(as well as release other dissolved gasses such as* $\mathbf{CO_2}$ *and* ***'hydrogen sulphide'*** *~* $\boldsymbol{H_2S}$*)* to cause the process to self-perpetuate. Initially catastrophic for marine environments, a sizeable methane eruption would cause the water column above to literally boil over with a variety of noxious gasses.

Besides liberating vast quantities of various greenhouse gasses into the atmosphere *(and rapidly accelerate the warming process)*, a 'clathrate gun' scenario would completely devastate much of the biosphere. Not only would large tracts of low-lying land become instantly flooded, but, methane trapped in 'heavier water droplets' would cause higher concentrations of this dangerous gas to be present in the breathable air. Potentially explosive, *'low-lying'* methane gas also brings a greater risk of firestorms, with resultant smoke and dust carrying even more 'climate-changing' pollutants into the atmosphere. In a worst case scenario the whole process could cause a *'runaway greenhouse effect'* leading to atmospheric conditions that are similar to those of Venus.

Another powerful greenhouse gas is nitrous oxide. With tremendous 'global warming potential', each $\mathbf{N_2O}$ molecule has almost 300 times the ability of $\mathbf{CO_2}$ to trap heat in the atmosphere. Whilst most nitrous oxide is produced naturally in the soil during the microbial processes of nitrification and de-nitrification, **a** of all atmospheric $\mathbf{N_2O}$ is a result of human activity, with modern agriculture the greatest anthropogenic source. Moreover, nitrous oxide can remain in the atmosphere for up to 110 years, and is largest single cause of stratospheric ozone decay.

Although far less abundant than nitrous oxide and the other greenhouse gasses mentioned so far, ozone also has a considerable impact on climate change ~ directly contributing to up to 7% of the current warming trend. A major constituent of photochemical smog, ozone is, a potent greenhouse gas which is produced at lower altitudes in the reaction of solar energy with pollutants and other greenhouse gasses. Whilst stratospheric ozone is important for life on Earth *(filtering out harmful ultraviolet wavelengths from the sunlight)*, ozone production at ground level damages plants by reducing their ability to uptake $\mathbf{CO_2}$. As a consequence, this anthropogenic ozone not only allows greater quantities of $\mathbf{CO_2}$ to build up in the atmosphere, but it can reduce the productivity of plants by up to 25% ~ having significant implications for global food production.

Water vapour, carbon dioxide, methane, nitrous oxide and ozone are not the only effective greenhouse gasses. Indeed an almost constant supply of synthesised greenhouse gasses are leaked into the atmosphere through various industrial processes. Agents such as ***'nitrogen triflouride'*** ***(NF***$_3$***)*** and ***'Hexaflouoroethane'*** ***(***C_2F_6***)*** have amongst the greatest *'global warming potential'* and the longest atmospheric lifetimes. As a greenhouse gas, each molecule of

'sulphur hexaflouride' (SF_6) for example, is 22,800 times more potent, per unit mass, than a $\mathbf{CO_2}$ molecule, whilst ***'tetraflouromethane' (CF_4)*** can remain in the atmosphere for up to 50,000 years. However, due to their comparatively low atmospheric concentrations, these and other manmade refrigerants, aerosols, and etchants are of lesser concern at the present time.

Yet the incessant emission of greenhouse gasses is not the only human contribution to climate change today. Another important contributor to the present warming trend is ***'black carbon'*** ~ a major component of soot and smoke. A highly potent 'climate-warming agent', black carbon arises from the incomplete combustion of fossil fuels *(namely through burning wood, coal and biofuels).* Also present in diesel engine exhaust, the radiative forcing of black carbon aerosols is immense even though they may remain in the atmosphere for only a matter of weeks. Indeed, these larger airborne particles have a profound effect on climate change, and can actually influence local rainfall patterns. Black carbon absorbs sunlight and so warms the atmosphere, speeding up the melting of snow and ice in many regions of the world.

Whilst the emission of soot particles has slowed considerably in Western Europe and parts of North America, it continues to rise steadily in the developing world. In the early 21st century, *'brown clouds'* of pollution from the burning of wood and fossil fuels started to appear over the Indian Ocean, where they have been found to increase the solar heating of the lower atmosphere by up to 50%. Curiously enough, by absorbing solar radiation at lover altitudes, black carbon can also 'dim' the surface of the ocean.

'Global** (or solar) **dimming' was originally discovered in the mid-1980's when it was found that the amount of solar radiation striking the Earth's surface had actually declined by more than 10% over the previous three decades, and appeared to contradict the growing evidence for global warming. However it is now known that the energy from photons of sunlight at sea level can be reduced by particulate pollution in the skies above, effectively masking warming at lower altitudes. Indeed humans have introduced an array of atmospheric pollutants including particles of soot, ash and various airborne sulphur compounds, all of which can serve to diffuse solar energy near the Earth's surface. At the turn to the present century, it was believed that solar dimming offset the effects of global warming by as much as 12%. Unfortunately, far from countering global warming, solar dimming has ultimately served to add potency to the phenomenon.

Whilst large volcanic eruptions can have an immediate dimming effect, rising levels of pollution also play a significant role. Caused largely by the combustion of fossil fuels *(as well as natural atmospheric particles such as salt and pollen)*, the effects of solar dimming are profound, and illustrate the immense human impact on weather systems. With more aerosols present in the atmosphere for water vapour to bind to, smaller but more numerous droplets tend to arise during cloud formation. This leads to larger clouds that are not as heavy with moisture, and so less likely to produce rainfall. Being larger, they reflect more sunlight but also reduce precipitation ~ seriously compromising the productivity of the planet's water cycle. Indeed they are even likely to have contributed to the failure of monsoon rains in Asia which, in turn, led to major famines during the 1970's and 80's.

Although it can clearly have serious consequences for human life, it was the more subtle effects of solar dimming that brought this phenomenon to the attention of scientists around the world. In the early 1990's it was noticed that over the previous 30 years there had been a global decline in the *'pan evaporation rate'* by as much as 4%. A method to measure the rate at which water evaporates at any given location, evaporation pans had been used in agriculture for many decades *(primarily to determine the suitability of conditions for particular crops)*. Only now however, was pan evaporation data being collected and quantified by climatologists. Solar dimming was given away by the fact that the rate of evaporation was seen to be falling, even though global temperatures were clearly rising. However this symptom of solar dimming was temporary and, by the mid-1990s, the overall trend in pan evaporation started to reverse *(most likely as a result of banning the use of sulphate aerosols throughout much of the developed world at this time)*. Curiously enough, since then there has been a steady rise in extreme weather conditions around the world as faster evaporation enables the atmosphere to store more energy.

Even though the effects of solar dimming have weakened considerably since the 1990's, they have not diminished completely. Indeed, a particularly noticeable change occurred across North America in the days immediately following the September 11 attacks in 2001. As a result of these attacks, **US** airspace was cleared of commercial flights and tight flying restrictions remained in place for three days. With most planes grounded, there was a small but significant shift in weather patterns throughout much of the **US**, with many parts of the country seeing daytime temperatures increase by over 1°**C** during this time. This happened because aircraft vapour trails effectively reduce the amount of solar energy reaching the ground. Indeed, it has been suggested that from 1970 to 2000 condensation trails of the world's aircraft actually led to a reduction of sunlight in some regions of the world by up to 22%. This should have led to cooler temperatures, but of course these effects were not noticed because they were offset by global warming. Yet whilst the 100,000 or so daily flights across the planet serve to mask the effects of global warming, aircraft emissions themselves contribute up to 10% of all anthropogenic greenhouse gasses.

There is little doubt that commercial aviation has contributed to climate change and helped to alter weather patterns around the world, but human activity has also affected atmospheric conditions at much higher altitudes. As greenhouse gas emissions *(largely anthropogenic* CO_2 *and methane)* have warmed up the troposphere, so they have subtly altered the temperature behaviours of higher atmospheric layers. As a result, the thermosphere *(lying between 53 and 440 miles above sea level)* has actually begun to cool. One serious consequence of this occurs above 180 miles high within the upper *(F)* layer of the ionosphere where ultraviolet solar radiation causes the ionisation of free-moving particles. This region of Earth's upper atmosphere is shrinking by some 2½ miles *(4km)* a decade, causing an increasing number of free electrons to migrate out into the exosphere where they are eventually lost to outer space. Whilst there are natural fluctuations within the various layers of the ionosphere, evidence for this ongoing atmospheric decay can be found in their steadily decreasing altitudes.

Although most hydrogen in the oxygen-rich lower atmosphere is locked up in water molecules, thermal energy can cause unfixed hydrogen in the outermost part of Earth's atmosphere to achieve escape velocity and leave the exosphere altogether. Indeed human activity has served to upset the natural balance of the atmosphere, with greater evaporation rates at the surface creating a latent heat flux that actually reduces molecular recombination higher up in the atmosphere ~ effectively causing it to 'leak' into space. Whilst long-term repercussions of this seem extreme *(it could ultimately compromise the integrity of the breathable atmosphere)*, accelerated rates of oxidation are already prevalent in the upper atmosphere.

The degradation of the ionosphere is a powerful indicator of climate change, which could ultimately have spectacular consequences for the life-sustaining atmosphere beneath it. Yet there are other, more determinable, symptoms of climate change ~ the frequency and brightness of ***'noctilucent clouds'***, for example, is steadily growing as both pollution and tropospheric warming alter the make-up of the upper atmosphere.

Located in the mesosphere, at some 50 miles above sea level *(making them by far the highest clouds of all)*, noctilucent clouds are formed by microscopic ice crystals and dust particles at temperatures below -120°**C**, and can only be observed during twilight hours in the summer months at temperate latitudes. This once extremely rare phenomenon is becoming more common for several reasons. When they react with hydroxyl radicals ***(HO)*** in the upper atmosphere, methane molecules produce frozen water vapour which can collect on minute dust particles and aerosols that result from various pollutants. Climate change has also improved the conditions for noctilucent clouds to form, with the mesosphere *(like the thermosphere above it)* tending to cool as the lower atmosphere warms up, making the extreme conditions *(necessary for noctilucent clouds to form)* occur more frequently. In addition, the degrading altitudes of atomic and molecular recombination within the upper atmosphere, has increased oxidation rates, which enables more methane reactions ~ thus serving to increase the production of ice crystals below the mesopause.

From the upper reaches of the atmosphere to the depths of the oceans, it is clear that mankind is destroying the natural mechanisms of climate stability across the globe. Moreover, the many components that maintain the precious life-sustaining conditions of Earth are closely integrated, and in changing the state of just one of these, we unwittingly alter the others. Indeed human activity affects the health of the entire planet and by continuing as we are, we ultimately jeopardise our own existence.

From another perspective, our Earth can be seen holistically as a complex interacting system which self-regulates its climatic, biospheric and geo-chemical conditions ~ with a tendency towards maintaining homeostasis. Without the presence of human beings *(and the short-sighted selfishness afforded to us by the liberating gift of 'intelligence')*, conditions on the planet would be perfect for most extant forms of life. This concept is most eloquently described by what has become known as the ***'Gaia hypothesis'*** ~ originally formulated in the 1960's by British independent research scientist **'James Lovelock'**. Named after the Greek mother Earth goddess, the Gaia hypothesis perceives the Earth as a living planet that functions as a single 'form' made of many countless interconnected parts. Despite its aberrant perspective, the Gaia hypothesis has gained much attention in recent years. Indeed since its inception, it has passed a number of predictive strictures, and is now supported by many environmentalists who regard it as being akin to scientific theory.

The Gaia hypothesis postulates that the biosphere is a self-regulating entity with the capacity to maintain the health the planet by actually controlling the chemical and physical environment. In other words, life provides the Earth with a homeostatic feedback system that brings a broad stabilisation of global temperature and chemical composition. The stability of atmospheric methane, for example, is only made possible by the existence of living organisms. Without the process of methanogenesis, global temperatures would be too low for many advanced life forms to survive, but in greater concentrations it is highly combustible, and without the oceans ability to absorb it, the atmosphere would be far too inhospitable for most extant species to even exist.

After bringing the idea to public attention in the 1970's, Lovelock argued that human disrespect for our planet and the resulting loss of biodiversity is reducing 'Gaia's capacity to maintain homeostasis. Human activity, by its very nature, has increased the potential for *'positive feedback loops'* and *'runaway global warming'*. On land, the loss of vast areas of forest has considerably diminished its capacity to act as a carbon sink, whilst the warming waters of the oceans reduce the rise of oceanic nutrients towards the surface in all but the polar regions ~ stifling algal blooms. Yet the continued health of 'Gaia's forests and plankton stocks is integral to her ability to buffer the effects of rising $\mathbf{CO_2}$, and our prolonged interference with these mechanisms is likely to bring sudden dire consequences for many species ~ including our own. Lovelock believed that the only viable option for civilisation is to embark on a policy of sustainable retreat, yet he realised that in reality this is unlikely to happen. Indeed, he envisaged the human race, at the turn of the next century, still existing on a warmer, comparably inhospitable planet ~ but in numbers vastly reduced from those of today.

Echoed by a growing number of climatologists and environmentalists, Lovelock's belief that it is *'far too late now to make any significant difference'* has become increasingly more likely over the past few decades. Whilst to many this attitude may seem deeply pessimistic, when you consider the sheer scale of what needs to be done to reverse centuries of human neglect, Lovelock's perception is more 'realist' than 'defeatist'. He considered current undertakings to reduce the ongoing effects of climate change, though commendable, to be wasted efforts. Indeed we are ultimately incapable of stopping the runaway global warming that we ourselves initiated.

Climate change today presents a huge range of problems for humanity and the future of civilisation. Global warming, for example, represents the single biggest health threat of the 21st century. Indeed, the health implications arising from the present warming trend are numerous and varied ~ ranging from exposure to higher levels of ultraviolet radiation, to the contamination of fertile and habitable land from persistent flooding. In many subtropical countries the increasing scarcity of freshwater is already putting an enormous strain on society, whilst the warming conditions in more temperate regions are helping certain viral infections and harmful bacterial strains to survive rather than die off seasonally. In fact as the planet has warmed, so the endemic regions of numerous tropical diseases *(including 'malaria', 'yellow fever', and 'dengue fever')* have widened considerably. With more diseases and their vectors able to survive higher latitudes, there is an increased likelihood that places such as Europe and North America will face unpleasant epidemics that could not possibly have occurred in the 20th century.

We live in an era of continued globalisation ~ the beginnings of which greatly assisted the proliferation of numerous diseases. *'Influenza'* and *'smallpox'*, for example, spread across the continents as a result of the European 'Age of Discovery', whilst the 'Industrial Revolution', two-and-a-half centuries later, enabled deadly diseases such as *'cholera'* and the third *'plague'* pandemic to take hold with devastating effect. These and many other diseases are, at present, largely kept in check by the use of anti-viral and antibiotic drugs, however poor hygiene and warming conditions raise the prospect that they could *(once again)* establish themselves within new host populations.

It is clear that the health and welfare of future generations of humans is already being compromised by climate change. In the face of this irreversible force of nature, we need to act swiftly *(and decisively)* if our species has any chance of survival. With so many changes afoot *(from shrinking water resources and rising sea levels, to the growing threats of deadly pandemics, and natural disasters)*, the world's nations need to multilaterally recognise and prioritise the many implications of climate change in order to lessen its inevitable impact on humanity. Yet even if this could be achieved it is highly unlikely that, by the turn of the next century, the Earth will be able to support anywhere near the human numbers that it does today.

We live at a time when our collective decisions will ultimately effect the future of not just humankind, but of all Earthly life. However, despite the clear scientific evidence that supports the fact that human activity has made *(and continues to make)* a significant contribution to the present warming trend, too many influential people around the world profit from the convenience of denial. Alas the ignorance *(and often greed)* of those in positions of power *(whether they be grounded in politics, economics, industry or religion)* has been detrimental to countless species *(including our own)* ~ threatening the very survival of many.

This short-sighted conflict of interest *(created by climate change sceptics and those with a vested interest in preventing curbs on emissions)* is particularly evident in the United States where a number of powerful, well funded organisations lobby against the acceptance of manmade global warming. Largely backed by wealthy industrialists and economists, they often attempt to blur the line between fact and fiction claiming, for example, that the current warming trend is the result of *'solar forcing'* whilst the influence of anthropogenic $\mathbf{CO_2}$ emissions on the climate is negligible. Some have even claimed that rising CO_2 concentrations in the atmosphere are the result, and not a cause, of global warming. All of these ideas are roundly debunked by the scientific community. Indeed there is no credible scientific contradiction to the fact that most of today's warming is manmade, and yet a significant minority of people 'choose' not to believe it.

Despite the rigorous testing of hypotheses based on clear data, there will always be those attempting to discredit scientific reports on climate change. But scientific rationale needs to prevail over the short-sighted perception of commercial gain. However, whilst 'political greed' and 'denial for convenience' present major obstacles to tackling climate change effectively, the greatest problem is a general unwillingness to act. This is because the global economy still depends heavily on the use of fossil fuels ~ a wholly *'environmentally unfriendly'* energy resource which has brought the high living standards enjoyed in the 'Western World', and an irresistible perception of communal wealth to which many developing nations aspire.

Alas, by enjoying the benefits of modern society, over a billion people worldwide now lead lifestyles that are ultimately unsustainable. Moreover, our dependency on non-renewable energy from finite natural resources makes human civilisation increasingly vulnerable as the decades pass. Yet the misplaced ideals of global markets means that economic growth is regarded as the most important factor for improving our lives, despite the fact that the ultimate problem is clearly rising human consumption itself.

During the first decade of the present century, global CO_2 emissions rose by around 30%, and this increase came almost entirely from developing countries. However a quarter of this rise resulted from the production of goods for consumption in wealthier industrialised nations. Indeed, modern society is sustained by continuing inequality, with around 20% of the world population consuming over 85% of all the natural resources taken from our planet. In order to redress the balance and improve the future prospects for our species as a whole, we need unified international action on a range of climate issues. Common-sense measures would include providing strict quotas for carbon emissions and encouraging industry to curb emissions through legally binding agreements. The creation of a 'carbon market' using incentives for reductions *(such as subsidies and grants)* and deterrents *(such as taxation for inefficiency and fines for non-compliance)* could sustain a meaningful global system of mandatory targets,

Unfortunately, in the current economic environment, trading rules inevitably succumb to the pressures of corporate lobbying. Since the 1970's and 80's, the most advanced industrial economies have all experienced considerable deregulation to ensure that governments do not 'interfere' with what is perceived by industry as the *'smooth running of the market'*. Faced with weak regulations, most heavily polluting industries simply exploit various loopholes in order to avoid taking *(often costly)* measures to curtail their carbon emissions.

As for the wider picture, since the 1990's there have been a number of international treaties aimed at reducing global CO_2 emissions. However by setting targets that are plainly unrealistic for many signatories *(and by being either legally non-binding or unenforceable)* they are effectively useless. Indeed most international agreements on climate change would be unlikely to reduce the effects of anthropogenic warming even if they achieved universal adherence.

The first significant international agreement designed to curtail anthropogenic warming was negotiated at the *'Rio Earth Summit'* in 1992, and the resulting ***'United Nations Framework Convention on Climate Change' (UNFCCC)*** is currently signed up to by 196 countries. Without enforcing any legally-binding limits, the **UNFCCC** aimed to stabilise greenhouse gas emissions *'at a level that would avoid dangerous anthropogenic interference with the climate system'*. Perhaps its biggest achievement however was to instigate the ***'United Nations Climate Change Conference'*** ~ an annual event *(since 1995)*, which assesses progress in tackling climate change and attempts to establish acceptable 'legal' protocols for reducing $\mathbf{CO_2}$ emissions in the developed world.

The most high profile international treaty is the ***'Kyoto Protocol'***, an extension of the **UNFCCC** which was adopted in 1997. Coming into force eight years later, the Kyoto Protocol was designed to reduce greenhouse gas emissions globally but only set out legally-binding targets for 37 of its 192 signatories. Whilst the emissions targets for developed countries are binding under international law, as developing nations most signatories have no such legal commitment, and these *'non-annex parties'* are free to regulate their own emissions at a national level.

Unfortunately the world's biggest polluters remain largely unaffected by the treaty. One notable absentee from the Kyoto Protocol is the **USA** which failed to ratify it ~ effectively pulling out in 2001. Meanwhile China, as a developing nation, argued that setting legally-binding limits on its greenhouse gas emissions would be unfair. Indeed several large emerging economies such as China, Brazil and India only ratified the agreement because it did not place such restrictions on their economic growth. In 2012 Russia and Japan elected not to take on any further commitments, whilst Canada withdrew from the treaty altogether in order to avoid paying large financial penalties for missing its targets. Moreover, most signatories of the Kyoto Protocol have thus far failed to reach even the most modest targets; their governments preferring to play the $\mathbf{CO_2}$ emissions 'blame game'. Indeed, when dealing with long-term issues, it is relatively easy to pass on responsibility for failure elsewhere whilst appearing to be progressive and constructive ~ which is exactly how many governments around the world appear to treat climate change.

Although the Kyoto Protocol itself may be ineffective, it has been useful as a focal point for international environmental action. The notion of dangerous anthropogenic climate change and need to combat it was consolidated, for example, at a ***'G8'*** forum in 2008 when the world's leading economies pledged to cut global emissions in half by 2050. A completely unrealistic target however, there has been little or no progress in terms of actual deeds; hardly surprising when you consider that the G8 nations themselves hold the greatest responsibility for perpetuating anthropogenic climate change ~ their governments continuing to finance projects and policies that contribute to it. Indeed, in Russia, for example, the system of *'carbon credits' (a Kyoto-*

compliant trading scheme designed to offset CO_2 *emissions)* has been widely abused ~ with several projects actually creating more greenhouse gasses, so as to destroy them in order to claim cash.

In terms of international agreements, another notable failure came at the 2009 '**UN** Climate Change Conference' with the subsequent ***'Copenhagen Accord'*** underpinning a general lack of commitment towards tackling global warming ~ particularly from nations such as the **USA**, China, India and Brazil. Indeed, whilst endorsing the spirit of the Kyoto Protocol, the Copenhagen Accord is a comparatively weak, non-binding agreement which highlights an endemic distrust between nations.

Alas even the measures required by the Kyoto Protocol *(and the various international agreements that have followed)* are nowhere near robust enough to stall today's rising temperature trends. Far more drastic measures *(which could never be realistically implemented)* need to be taken in order to mitigate the worst effects of climate change. These include reducing consumer demand for heavily polluting goods and services, drastically increasing the efficiency of the global energy supply, preventing further deforestation, and completely phasing out technology that requires the burning of fossil fuels.

Of the many schemes and projects around the world designed to tackle climate change, most are morally commendable ~ though our current endeavours to curb global warming are ultimately wasted on fighting what is essentially 'a lost cause'. Nevertheless important work **is** being done by a number of institutions and collectives to increase our awareness and understanding of climate change *(even if governments still lack the will to do anything serious about it)*. These include the ***'World Meteorological Organization' (WMO)*** ~ a specialised **UN** agency that provides the framework for international co-operation on climate issues. Another is the ***'Global Carbon Project' (GCP),*** which seeks to quantify the effects of anthropogenic emissions and fully understand the workings of the carbon cycle. Comprising a global network of scientists and economists who collectively work on a wide range of data, the **GCP** aims to compile an accurate picture of atmospheric CO_2 and determine the efficiency of existing carbon sinks. Then there is the ***'Climate Action Tracker' (CAT)*** ~ an international consortium of research institutions that analyse the commitments already made by governments, and highlight their shortcomings.

Perhaps the most authoritative contingent on global warming however is the ***'Intergovernmental Panel on Climate Change' (IPCC)*** ~ a **UN** body that assesses the impacts of climate change and advises the international community accordingly. Established in 1988, the **IPCC** comprises representatives from 140 countries and involves over 4,000 scientists from around the world. It produces six-yearly assessment reports that consolidate established facts regarding climate change and project its likely future impacts. Every aspect of the global climate is investigated ~ from minute changes in atmospheric composition to the shifting dates of bird migrations. **IPCC** reports are considered to be a fair reflection of the views of the scientific community as a whole, and their conclusions, once published, are generally accepted by governments worldwide.

Despite their undeniable scientific legitimacy, **IPCC** reports have been subject to unfounded criticism from climate change critics, whilst the studies of numerous scientists and researchers have endured baseless attempts to discredit them. The body itself was temporarily scarred in 2009 by what became known as the *'Climategate scandal'*. After the hacking of an **IPCC** server, thousands of private documents and e-mails were leaked, with some purporting to show collusion between climatologists in order to make their data fit accepted models of human-induced warming. With excerpts deliberately taken out of context, the claim that 'global warming was a scientific conspiracy' proved to be totally unfounded. However this episode was not helped by the debacle two years earlier, when it was erroneously claimed that Himalayan glaciers would completely disappear by 2035. Although it stemmed from the misreporting of an unpublished **IPCC** 'working group' study, the prediction nevertheless gained a great deal of media attention and was seized upon by global warming conspiracy theorists around the world.

As a result, the **IPCC** *'Fifth Assessment Report' (finalised in 2014)* was very cautious in its assessment of future climate change ~ emphasising established facts about global warming rather than projecting possible outcomes. It highlighted, for example, the ongoing loss of mass from the world's glaciers and polar ice sheets, whilst reiterating the fact that, since the mid-19th century, the average sea level was rising faster than at anytime in the previous two millennia. It also confirmed that atmospheric $\mathbf{CO_2}$ was now 40% greater than it was prior to the industrial age ~ with concentrations of greenhouse gasses higher than they had been for at least 800,000 years.

Whilst the **IPCC**'s iteration of recent climate research primarily emphasised the current health of our planet, the report also confirmed that, since the mid-20th century, human influence is a dominant cause of observed warming. Indeed it concluded, with 95% certainty, that anthropogenic factors are influencing climate change and contributing to at least 50% of the current warming trend. Furthermore, it pointed out that 'ocean warming' accounts for around 90% of all energy stored within the climate system ~ inevitably leading to increased acidification. Ongoing changes in the global water cycle will continue to accentuate periods of flooding and drought, with unusual weather patterns invariably giving rise to greater meteorological extremes.

Published in the wake of *'climategate'* and the *'Himalayan glacier controversy*', the 2014 **IPCC** report pointed out that its conclusions were based on improved scientific methods and better data than had been available for previous reports. As a result of this, it stressed that the most extreme scenarios of some earlier predictions were now considered less likely, with current models producing more 'realistic' estimates of the future impacts of climate change. For example, it concluded that, by the end of the present century, the sea level will most likely have risen somewhere between .45 and .82 metres *(1½ft. - 2ft.8)*, whilst average global temperatures by then are unlikely to exceed 4°C. In truth the predictions attained using these models are very conservative, with a 70cm. rise and the 4°**C** increase more likely to be reached sometime before 2080.

The report also paid particular attention to a perceived lull in the present warming trend since 1998. Observed in isolation, this apparent slowdown in the average global temperature rise did not seem to follow predictive models. However, taken within the context of a longer time frame, there are several potential reasons for its occurrence. For a start, 1998 was an exceptional year for oceanic activity ~ coinciding with the beginning of a sustained warm phase in the ***'Atlantic Multidecadal Oscillation' (AMO)*** as well as one of the most powerful ***'El Niño' Southern Oscillation' (ESO)*** events in recorded history. Both occurrences represent a natural cycle of ocean temperatures whose mode of variability has considerable amplitude ~ with only the 'seasonal cycle' having a greater influence on climatic conditions around the world. Indeed the amplitude of equatorial sea surface temperatures in the Pacific Ocean *(that give rise to El Niño and 'La Niña' conditions)* is the most important component in the year-to-year variability of global average temperatures.

Affecting everything from the strength and duration of typhoons and monsoon systems in Africa and Asia to the frequency and severity of hurricanes and droughts in the Americas, the irregular El Niño phases in the Pacific and the prolonged cycle of the **AMO** in the Atlantic have a profound effect on the state of the global climate. In fact the importance of the role played by oceans in climate change cannot be understated. Not only can these oceanic processes affect global weather patterns for many years, but the oceans themselves absorb the impact of rising $\mathbf{CO_2}$ emissions ~ storing excess heat which is likely to re-emerge when the saturation point is reached in the coming decades. Indeed whilst terrestrial temperatures may have experienced a warming hiatus since 1998, the mean ocean temperature has steadily continued to rise.

An interesting comparison can be made between the warming hiatus at the start of the present century and one that occurred between 1945-70. Despite the rebuilding and rapid expansion of European and the **US** economies creating a *'coal boom'* in this period, industrial warming actually slowed. Then, the constant build up of city smog served to mask the warming effect of burning vast amounts of fossil fuel in the first place. During the first decade of the present century, coal consumption in China more than doubled, yet the ongoing rise in global mean surface temperature has once again slowed ~ this time as photochemical smog has become a growing problem for many East Asian cities. A cause of acid rain and excessive atmospheric pollution, the burning of coal has a huge environmental impact ~ yet to many emerging economies its perceived value is enormous. However coal usage will inevitably wane *(as it did in the West after the post-war industrial expansion)*, and the recent hiatus *(like the one before)* will prove to be but a temporary reprieve from an extant warming trend that shows no sign of stopping.

Unfortunately global efforts to tackle climate change are too little, too late. Indeed they are paltry compared to the efforts actually required to face such a daunting challenge. However, over the coming years, as climate change continues and global warming is regarded as practically unstoppable, mankind will become increasingly desperate to find solutions in order to survive. As a result, in the not-too-distant future, we are likely take extraordinary risks by attempting to repair the damage through *'climate intervention'* ~ using technology that could potentially mitigate the effects of global warming, but could equally have unknown *(and potentially irreversible)* harmful consequences.

Designed to stall *(or even reverse)* the effects of global warming, ***'climate engineering technology'*** is primarily based around two concepts: *'carbon dioxide removal'* and *'solar radiation management'*. Of the former branch, various methods have been suggested for storing excess $\mathbf{CO_2}$ ~ including the use of *'artificial trees'*, *'biochar'* and *'enhanced weathering'*. One strategy to remove excess $\mathbf{CO_2}$ is to seed ocean waters with iron as a way to increase phytoplankton blooms. Another technique involves the construction of large ocean pumps to bring nutrient-rich water up from below the thermocline, again to fertilise algae in the surface waters and encourage them to bloom. The basic idea is to accelerate the transfer of $\mathbf{CO_2}$ from the atmosphere to the oceans by increasing primary production and enhancing the export of organic carbon *(as marine snow)* to deep water. Of course, by introducing even more atmospheric $\mathbf{CO_2}$ into oceans that are already becoming increasingly acidic, we relieve one problem but force a far bigger one.

Particularly concerning though is the idea of 'solar radiation management' ~ a myriad of proposed and theoretical projects designed to reflect some of the Sun's energy away from the Earth's surface by increasing our planet's albedo. Perhaps the most drastic idea is to remove swathes of the northern Boreal Forest so that more sunlight would be reflected off the empty snow-covered landscape that replaces it. Another strategy is to spray clouds with seawater ~ the idea being that salt crystals would allow more water vapour to condense in the atmosphere ~ creating larger, whiter clouds which are naturally more reflective. A proposal with potentially catastrophic consequences, particle size would be crucial to the desired formation, whilst adding salt to the atmosphere is certainly not a good idea. Such a scheme could irrevocably change rainfall patterns and destroy existing natural oases. Indeed by increasing forest dieback and destroying important carbon sinks, it could actually have the opposite effect.

An equally ill-conceived strategy is to burn sulphur in the upper atmosphere in order to create a haze, and thus increase the planet's albedo. A delivery of sulphate aerosols into the stratosphere though could potentially lower global temperatures, with an injection of gasses such as 'hydrogen sulphide' ***(H_2S)***, 'sulphur dioxide' ***(SO_2)*** and 'sulphuric acid' ***(H_2SO_4)*** serving to enhance the 'global dimming' effect. However it could also hasten ozone layer depletion and bring serious health risks to numerous plant and animal species. Alas the idea could never be safely tested first.

Climate intervention could have a profound effect on an array of atmospheric systems; increasing the health of some, but the stress of others. By purposefully disrupting the natural balance of various climate mechanisms *(and ecosystems)* without considering the full implications, large-scale $\mathbf{CO_2}$ removal and solar radiation management techniques such as these are today considered *(by many people)* to be highly unethical. However, they will inevitably seem less so as our species becomes ever more desperate to reduce the pace of global warming.

The fine balance of the interconnected web of ecosystems that make up our Earth's biosphere is best illustrated by failed human attempts to replicate it. The ill-fated experiments between 1991-4 at the ***'Biosphere 2'*** facility in Oracle, Arizona are case in point. With over three acres enclosed in a sealed 'greenhouse' complex, Biosphere 2 housed a series of miniature biomes representing a rainforest, a savannah grassland, a fog desert, a mangrove wetland, a coral reef and even an ocean environment. In addition it included areas for an agricultural system, as well as for human habitat ~ all completely sealed off from the outside world. Indeed, apart from the use of an independent water system to control heating and cooling within the complex, only electricity was externally supplied.

Throughout the original project, the continuously changing chemistry of the water, air and soil was closely monitored, and the many difficulties in maintaining a healthy self-sustaining biosphere soon became apparent. For a start, $\mathbf{CO_2}$ levels fluctuated wildly, and within a few months the biomes were unable to sustain human life without the introduction of more oxygen. Without further intervention, the general health of the enclosed environments slowly degraded, with everything from the psychological wellbeing of the human subjects to overall biodiversity falling into decline. Of the animals that had been introduced, most vertebrate species and all pollinators eventually died off ~ inevitably bringing human participation to an early end. Cockroaches and ants, on the other hand, thrived in the deteriorating conditions.

Picture a nightmare future scenario where modern society can no longer survive the effects of the ongoing environmental decline. Imagine that, by the middle of the current century, the unsustainable ecology required to support the burgeoning human population leads to an agricultural crisis. Thanks to climate change, weather systems have become more extreme, whilst established seasonal patterns and cycles are increasingly erratic and unreliable. As a result, vast tracts of fertile agricultural land are lost through flood or drought which, combined with wholesale mismanagement of the land, leads to a serious shortage of food. With dwindling supplies of fresh water *(and the loss of thousands of miles of coastline to rising sea levels)*, millions of people become displaced ~ even in the world's wealthiest nations. Failure of the rains in some of the most densely populated regions of the world cause famine and disease, whilst countless vulnerable ecosystems are destroyed *(along with local food chains)* as thousands of desperate people ravage nearby natural habitats in order to survive. Elsewhere, the overfished and increasingly polluted oceans and waterways bring about the complete collapse of vital fish stocks, sending millions more people into poverty. Meantime the increasing scarcity of natural resources *(such as oil, and of course fresh water)* result in the spiralling prices of many essential commodities, further widening the gulf between rich and poor. As competition for scarce resources becomes increasingly cut-throat, human civilisation comes under ever greater stress, until complete social breakdown eventually ensues.

This may seem like a wholly pessimistic glimpse of the future, but one key factor is pivotal in determining the likelihood of such a depressing outcome for humanity ~ and that is the availability of fresh water and fertile soils. In reality, the total area of arable land around the world has been in general decline since the late 1990's, whilst global water consumption almost quadrupled during the last century. With water tables around the planet continuing to fall, by 1990 over a billion people did not have sufficient access to clean water for their basic necessities ~ even though there would have been enough for everyone if it were evenly distributed. Indeed the scarcity of fresh water in many parts of the world is rooted in poverty and inequality rather than physical availability. Yet with supplies diminishing every year, by 2025 over 2.7 billion people around the world are expected to experience severe water shortages. With climate change and pollution seriously depleting 'safe drinking water' and 'proper sanitation', up to two thirds of the entire human population will likely be affected in one way or another.

Today, around 80% of the world population live in regions where the freshwater supply is insecure. Throughout most of Europe and much of the **USA**, water supplies are under some degree of stress, but here engineering technology is employed to mitigate the ongoing threat to water security. A network of dams, reservoirs, canals and pipelines ensures that nearly every citizen has full access to fresh water at any time. Water safety however is a big problem in parts of China and India, for example, where the lives of hundreds of millions of people are at risk as a result. Here, agricultural and industrial pollution of water supplies through neglect, corruption and poor water management, can be compounded by drought ~ leading to a serious shortage of available fresh water.

One profound consequence of global warming is an increase in human conflict. Indeed it is widely recognised that the adverse effects of climate change *(particularly in areas where tensions are already running high)* can actually aggravate a hostile situation, and it constitutes a major threat to international peace and security. There is growing unrest in poorer regions where the scarcity of drinking water has increased, or where crops have failed due to sustained periods of drought. In fact the degradation of fertile land has been a major driving factor for conflicts in Africa for many decades.

It is clear that the current environmental crisis ultimately has the potential to spark global poverty, famine, disease, political and civil unrest, and of course serious conflict. The semi-arid regions of Africa and Asia face the most immediate danger, with serious environmental disasters here most likely to catalyse a desperate collapse into war. In countries such as Namibia, Ethiopia and Sudan, for example, the loss of precious water resources *(thanks largely to gross mismanagement)* has fuelled violent conflict ~ occurrences of which are becoming increasingly common throughout sub-Saharan Africa. Meanwhile in the Middle East, a heady mix of religious fervour and political intolerance add to environmental pressures, making it a particularly vulnerable region *(and the potential 'Achilles heel' of today's global civilisation)*. Here, the control of water supplies and oil resources can bring enormous power and wealth to a privileged minority in an area where religious hatred is already the cause of great tension and countless historic wars.

If our planet could actually provide a never-ending supply of natural resources, then human conflict would not be as prolific as it currently is. As far as the world economy is concerned, the most recent global recession would almost certainly not have occurred if we lived on an eternally fruitful planet. Indeed, we would be faced with the prospect of endless growth powered by limitless consumerism, spreading unchallenged though out the world. This, of course, has certainly not been the case, with the dominance of western values and ideals coming increasingly under threat as natural resources diminish, and climate change threatens continued prosperity.

Yet from a global economic boom at the end of the 20th century emerged vast modernisation programmes in some of the world's most heavily populated countries. By the start of the current century, the emerging economies of China, India, Brazil, South Africa and Mexico had grown to such an extent that between them they were using up almost ¾ of the Earth's total biocapacity. Defined as an ecosystem's ability to produce natural resources and reduce harmful substances, the overall biocapacity of our planet is gradually being eroded by human activity. As a result there is a sense of urgency ~ not so much to repair the damage, rather to exploit what remains. This rush for control of 'untapped' natural resources is most apparent in remote polar regions. In the Arctic Circle, for example, Russia, Canada, the **USA**, Norway and Denmark all have remote territories that overlay enormous reservoirs of oil and gas. Since 2007 Russia, in particular, has laid claim to vast swathes of the Arctic seabed, much of which is disputed by other nations, including the **US**.

Our 'modern' global civilisation, it seems, exists as somewhat of a paradox. Whilst we value certain natural resources to the point of massive environmental neglect, in order to be sustained, modern society clearly depends on the continued health of ecosystems that are themselves getting ever weaker. Anthropogenic climate change will inevitably put civilisation under unprecedented social and economic stress, and ultimately billions of people will die as a result. Horrendous for the poorer populations of developing countries, the likely outcome will also be devastating for those in the developed world. Indeed, the fragility of modern life becomes clear in times of major disaster. You only have to explore the anarchy that ensued in New Orleans in the aftermath of ***'Hurricane Katrina'*** in 2005 to get an idea of the vulnerability of modern society.

Every day, in the early the 21st century, approximately 150 plant and animal species become extinct, some 70,000 hectares of rainforest is destroyed, and around 150 million tonnes of carbon dioxide ***(CO_2)*** is released into the atmosphere. The world's oceans and waterways are also becoming seriously degraded as they are warmed by climate change. Not only is the absorption of atmospheric **CO_2** making the oceans increasingly acidic, but they are also suffering from overfishing and pollution. Moreover, each year our species consumes more resources and produces more waste ~ putting the biosphere under ever more pressure to *'provide and absorb'* for the swelling human population. It is highly likely that, by the late 2020's, the conducive climate conditions under which human civilisation has developed, will be lost forever.

During the 2010s, global oil production averaged almost 90 million barrels a day. When you add to this the daily consumption of coal *(at around 20 million tonnes)* and natural gas *(at about 9.3 billion cubic metres [or 320 billion cu ft.])* it becomes clear that, if we continue to rely so heavily on fossil fuels, the industrial heart of human civilisation cannot possibly be maintained for much longer than a few more decades. Yet we still exploit these natural resources for our growing energy needs as if there were an indefinite supply.

Alas our perpetual thirst for oil, coal and gas since the late 18th century has been the cause of irrevocable environmental damage. Indeed human beings are responsible for a significant percentage of the greenhouse gasses that are released into the atmosphere every year, and around 70% of these 'anthropogenic emissions' emanate from cities *(which themselves occupy less than 2% of the world's land cover)*. As our cities grow, so does our consumption of fossil fuels ~ and at an ever-increasing rate. Indeed, during the first decade of the 21st century annual emissions of **CO_2** *(the primary greenhouse gas)* increased by around 32%. Yet emissions had already risen by some 30% over the course of the previous two decades.

It is clear that human activity can exceed natural processes, and we, as a species, have inadvertently begun a whole new geological epoch. Named the ***'Anthropocene'***, human activity over the past few millennia has left a signature in the rock that will still be recognisable in millions of years time. The first signals of the Anthropocene were laid down in sediment as a result of early metalworks some 5,000 years ago. However the greatest concentration of 'unnatural' materials to find their way into the soil will have occurred over the past two-and-a-half centuries ~ since the onset of Industrial Revolution. Today, accumulations of plastics, metals and other manmade materials such as concrete and refined asphalt are evident around the planet both on land and in the oceans, whilst a growing number of artificially-produced gasses and aerosols pervade the atmosphere.

Mankind's very existence places an enormous strain on the natural world, with our activities effecting countless species and numerous ecosystems around the globe. In fact our collective impact on the climate, the oceans, and the biosphere as a whole is unprecedented. With over 8 billion people and rising, the human population has effectively smothered the natural order of life in many parts of the world. Indeed the average area that is exploited for food, water, energy, housing, transportation and waste disposal in order to sustain a single individual living in the **USA,** for example, is a whopping 97,000 square metres *(or 24 acres)* of productive land and shallow seas. Furthermore the rest of the developed world *(along with emerging economies such as China, India and Brazil)* ensures that the environmental cost of human existence is simply staggering.

It is generally accepted that the human population first exceeded Earth's sustainability in 1978, and the natural world today is vastly over-stretched to the point that global consumption would need to be drastically reduced if human civilisation were to be made sustainable. Even so, by 2009 the number of undernourished people in the world passed the one billion mark, with South-east Asia and sub-Saharan Africa the worst affected regions.

Despite growing starvation in the world's poorest nations, in 2010 it was estimated that, within his or her lifetime, each human being consumes goods and services worth, on average, 1.3 tonnes of carbon. This figure is, of course, far higher in the industrialised world, with each American citizen, for example, leaving a huge 'ecological footprint' that's nearer 16 tonnes of $\mathbf{CO_2}$. Indeed, so great is the **US** demand on Earth's ecosystems, that if everyone consumed resources at the same scale as American citizens, eight planet Earth's would be needed to sustain the human population. Furthermore, over-consumption is on the increase, and a growing number of people around the world are leading exorbitant lifestyles. Indeed the habit of wasteful consumerism has become ingrained within many disparate societies ~ with the emerging huge economies of China, India and Brazil prompting the most rapid cultural changes.

With the world population growing at a steady rate *(we are expected to pass 9 billion in number by 2043)*, human beings place ever-greater stress on the natural environment as we exploit it for whatever valuable resources we can. Yet we are hugely wasteful, and our careless exploitation of land and sea compounds the damage that we do. Farming, for example, is essential for our very survival, and we destroy vast tracts of natural wilderness in order to create new farmland. Yet each year between 30-40% of all crops are lost to pestilence or disease before they are harvested. Another threat to crop production is the continuing loss of fertile land to salt damage. Salt degradation primarily results from the drying out of land that has no natural drainage, and by 2014 over 240,000 square miles of poorly irrigated farmland around the world had been lost this way.

Modern agriculture is also very water intensive *(especially livestock farming)*. In short, every calorie of food requires around 1 litre *(3pts)* of water to produce it. This means that, on average, each person needs 2-3,000 litres *(between and 500 and 800 gallons)* of water to healthily sustain their daily food requirements. Indeed, agriculture accounts for around 70% of entire global water usage. Moreover modern farming massively increases the amount of reactive nitrogen in the environment, as well as contributing a significant proportion of anthropogenic greenhouse gas emissions.

Numerous natural ecosystems *(that have not already been wiped out by farming, industry or urbanisation)* are today being degraded at an unprecedented rate. Besides suffering the ill-effects of pollution and climate change, a number of large-scale ecosystems face complete collapse as a result of rising global consumption levels. By 2003 human demand had exceeded the planet's biocapacity by 25%, with our global ecological footprint continuing to grow ever larger. Indeed it is highly likely that human civilisation will face a serious global crisis over the coming decades as demand for food, water and energy far outstrips the Earth's ability to provide.

Besotted with the idea of material wealth, most governments today *(regardless of whether they are democratically elected or totalitarian)* support an economic foundation that is ingrained with 'Westernised ideals'. As a result, a vast majority of populations are ruled by economic policies that are geared towards improving their country's 'gross domestic product' *(or **GDP**)*. Used to measure the economic size of a nation, **GDP** provides a short-term vision of prosperity, and ultimately perpetuates the notion that people are best served by nationalistic agendas. Placing greater importance on trade balance than on environmental well-being, the prime aim of most governments is to stimulate what is effectively unsustainable growth and consumption. Alas there is great financial benefit to perpetuating this mindset and most people remain wilfully ignorant of the eventual consequences. Although the idea that we are merely *'harvesting a fruitful planet whose resources are virtually inexhaustible'* may seem absurd, we continue to consume goods and services at levels that will be impossible to sustain beyond a few more years.

Unfortunately, although climate change is going on all around us, it is largely imperceptible in our day-to-day lives, and has little impact over the political timescale of the four to five years that politicians in most democratic states are concerned about. Yet our world's most valuable resources *(namely fresh water and arable land)* are diminishing at an alarming rate. Continued population growth will eventually overwhelm the planet's limited resources, increasing the likelihood of famine, social chaos and war. Indeed the very stability of modern society is intrinsically connected to the health of the natural world, and climate change will invariably challenge the capacity of humans to adapt to a rapidly changing environment. The ominous reality of our persistent exploitation of nature is that, through our uniquely human perception of wealth and ownership *(concepts which have no bearing on the natural world outside of human perspicacity)*, we are ultimately self-destructive.

Yet the 'invaluable' natural mechanisms that sustain life on Earth and keep our planet so bountiful, actually have perceived financial value too. By 2010, the annual cost of destroying the environment was believed to be up to 10% of the global **GDP**. As forests decline and oceans die, so nature stops providing services that were once essentially free. As a result the 'human economy' has to provide for what it takes from nature *(such as building reservoirs to sustain large populations or farming foods that once grew wild)* and all at a considerable financial cost.

The financial impact of global warming was perhaps best illustrated in 2006 by the ***'Stern Review on the Economics of Climate Change'***; a British government report that forecast dire consequences for the world economy unless immediate steps were taken to limit its effects. Indeed it concluded that without urgent action, global warming would likely shrink the world economy by up to 20% each and every year. Claiming that it would currently cost about 1% per annum of global **GDP** to stabilise the worst effects of climate change, the 'Stern Review' emphasised that the longer action was delayed, the greater the cost would be to the world economy. In 2010, a British environmental think-tank known as the ***'New Economics Foundation'*** reasoned that it simply wasn't possible to reconcile continued economic growth with the necessary carbon reductions required to limit temperature rises to 2°**C**. Furthermore, it concluded that, if we are to survive the 21st century without unprecedented loss of life, human civilisation urgently needs to undergo profound systematic changes that transcend national boundaries.

Alas, it is clear that there still remains a lack of real socio-political desire for proper ecological management of the planet. Indeed as intellectual guardians of life on Earth, we continue to negate our responsibilities because of an ignorant majority. This happens even though the continuing destruction of ecosystems has cost the global economy over '$2 trillion' every year since 2009. The greatest threat to the health of the environment is 'corporate and personal greed' ~ i.e. the inexorable creation of material wealth through the exploitation of the natural world. Of course without exploiting nature, modern civilisation simply could not exist. But most people fortunate enough to live in the Western world readily accept a 'way of life' that, although hugely wasteful, is barely given a second thought. In fact it is thoughtless human greed that perpetuates a particular mindset within all modern societies that is so detrimental to the living planet.

In the United States *(the wealthiest of all Western nations)*, modern industry is politically empowered through lobbyists who have enormous influence within the American electoral system. Indeed they are hugely successful at stifling legislation that could hurt the interests of their corporate backers. Some even directly try to redress the balance of opinion in America concerning an array of environmental issues. The very idea of *'man-made global warming'*, for example, has seen numerous concerted attempts to be discredited over the past few decades despite the growing scientific evidence to confirm it. Powerful institutions and organisations that lobby against the acceptance of anthropogenic climate change were responsible for instigating and seizing upon the so-called *'Climategate'* affair in 2009. Amid spurious claims that the conclusions of most scientific papers presented to the '**IPCC**' were exaggerated in order to be noticed during the process of peer-review *(and so get published)*, some lobby groups actively promoted pseudo-science that further eroded the public perception of global warming. It was claimed, for example, that many weather stations had become increasingly unreliable due to the *'urban heat effect'* from growing cities, and this had not been taken into account when projecting future warming trends.

Despite the validity of anthropogenic climate change having been confirmed by numerous scientific studies, those with a vested interest in promoting its denial or 'lack of significance' will persist in raising doubt. It is simply human nature to contest things that can hurt us financially, even if it's for the greater good. Unfortunately we are too selfish to gain a collective sense of responsibility for our actions before we commit irrevocable environmental damage that will ultimately harm us all. It is the genetic heritage of human beings to place 'self' first, 'family' second, 'tribe' third and everything else last. Furthermore, as a species, we are not predisposed to plan ahead for one or two generations at the most.

Nature is obviously not adequately valued by human beings, yet the global economy is losing far more money from the disappearance of forests than from the prolonged recession and banking crisis that began in 2008. The health of the Earth's ecosystems is vital for the continuation of 'free natural services' *(such as established hydrological cycles that provide fresh water, and natural drainage systems that maintain fertile soils)*. Essential for activities such as agriculture, forestry and fisheries, without them our global civilisation simply could not exist. Yet a number of these so-called 'free services' are in dramatic decline thanks to our irreverent destruction of numerous irreplaceable natural assets. It was estimated in 2012, for example, that the annual cost of deforestation was up to $5 trillion and rising. Indeed forest decline has a serious impact on natural services including the absorption of CO_2 and the provision of fresh water. Moreover, with a little under half of all medicines derived from natural products *(the global value of plant-derived pharmaceutical products alone is currently worth in excess of $500 billion per annum)*, the steady loss of forests today will likely have a devastating effect on the health of future civilisation.

It's not just deforestation that has a serious impact on the global economy. The stress on the world's fish stocks, for example, has caused the annual value of trade in oceanic fisheries *(worth over $6 billion in 2010)* to increase six-fold in a little more than three decades. Indeed around 40% of all world trade is directly based on biological products or processes. Yet 'human fixes' *(such as building reservoirs to provide fresh water that was once abundant, or farming foods that were once naturally available)*, ensure that the cost of our unbounded exploitation of nature is rising sharply. 'Indeed it is highly probable that we have already passed a tipping point that will ensure the planet's continued loss of biodiversity over the next few millennia. This can only be to the detriment of all surviving species, not just our own.

Footnote

When examined in the context of an overall warming trend, the processes involved in this recent 'pause' can be explained scientifically. By applying strict chemical laws to the atmospheric system as a holistic entity, the following reasoning has foundation: Whenever the temperature rises, dissolved gasses are invariably boiled off. This initial out-gassing removes heat from the system, causing non-linearity. As the temperature continues to increase, any dissolved liquids with a boiling point below that of water will fractionally distill. This would cause an ongoing rise in temperature to temporarily cease before continuing.

iii.

*(**Interlude:** Our unhealthy obsession with material wealth)*

Although the devastating impacts of anthropogenic climate change are becoming increasingly evident around us we, as a species, remain preoccupied with making money. Most people primarily perceive the accumulation of personal wealth as a means of empowerment ~ bringing greater security and happiness to themselves and their kin. In most democratic countries, the wider community is also served by local and national governments which strive to generate wealth in order to improve things such as infrastructure and services ~ and so better the lives of its people *(or at least a privileged minority)*. Indeed our obsession with creating material wealth is so ingrained in *'Western values'* that we place the economic health of our nations above the physical health of Earth's natural environments. Yet the *'capitalist'* perception of success and well-being is innately flawed and ultimately self-destructive.

Our *(almost)* irresistible urge to create wealth is such that stock markets around the world are grossly overvalued. As the world's largest economy, the **USA** is home to the world's largest stock exchanges whose listed companies had, by 2020, a combined market capitalisation of almost $45 trillion. Situated in ***'Wall Street'***, deep in the city's financial district, the ***'New York Stock Exchange'*** is by far the largest of all, although there are dozens of other stock exchanges worth over $1 trillion ~ including important financial hubs in London, Tokyo and Shanghai.

Despite the financial crisis of 2008 *(which caused a prolonged global recession),* countless capitalist ventures around the world have created a commodities boom that continues to this day. It is clear, however, that when the inevitable happens and essential resources are exhausted, the financial 'bubble' that keeps modern civilisation afloat will eventually burst ~ the creation of wealth simply cannot continue indefinitely. Indeed, virtually all human activity is dependant, in some way or other, on the use of natural materials, and the depletion of important resources will bring financial turmoil. Just as Wall Street is at the centre of American commerce, so the **US** is at the heart of the global economy. It stands to reason, therefore, that should the American economy ever falter beyond recovery, there would be unavoidable contagion throughout the global markets ~ with the subsequent reverberations creating panic and international instability.

A cornerstone of 'western civilisation', the health of the American economy has an enormous influence on the global outlook, and this has been the case for well over a hundred years. The ***'California Gold Rush'*** in the mid-19th century and the ***'Texas Oil Boom'*** of the early 20th century, for example, both generated enormous wealth in the **US**, and served to stimulate economies elsewhere the world. The ***'Wall Street Crash'*** in 1929 and the resulting ***'Great Depression'*** in the 1930's however had a crushing impact on the global economy at the time. More recently American capitalist ventures lay at the heart of the *'dot-com bubble'* in the 1990s, which collapsed at the turn of the present century, causing numerous communication companies to file for bankruptcy. Then of course there was the **US** *'housing bubble'* in the early 2000's, the collapse of which led to a *'credit crunch'* and a subsequent financial crisis that spread around the world in 2008 ~ resulting in what became known as the ***'Great Recession'***.

The global financial crisis of 2008 was also a crisis of economic theory. Up until this point, American capitalism was free to operate within a system where regulations governing the trading between financial institutions were comparatively few. Financial regulators allowed a free competitive market to flourish under the assumption that the 'market system' was self-stabilising. Indeed, it was widely accepted that market value is determined by the masses *(the so-called wisdom of average)*, and it was considered foolhardy to question it. This allowed assets to rise sharply through speculative price increases that were simply not justified.

The collapse of the **US** property market is a prime example of what happens when traders knowingly buy goods well above their intrinsic value in the expectation that someone is willing to pay an even higher price. This reliance on the ability to sell questionable investments to a *'greater fool'* is prevalent in trading both within the housing market and the art world. Perhaps the most dramatic example of the *'greater fool theory'* however occurred in the Far East when, in 1987, persistent overvaluation contrived with market liquidity to bring about a sudden lack of confidence in the marketplace. In this case, the market collapse at the ***'Hong Kong Stock Exchange'*** was exacerbated by poorly managed 'program trading', culminating in a rapid global crash that became known as ***'Black Monday'***.

Whilst the Black Monday event of 1987 represented a severe and sudden collapse *(the value of shares across the globe fell between 20% and 60% within a single day)*, the markets recovered quickly and were trading at 'pre-crash' prices in a little over a year. This was made possible by **US** banks continuing to lend to one another *(initially at a loss)* ~ a policy which actually increased investor confidence in the system and lay the foundation for further growth. The failure of the markets in 2008 however was altogether more deep-seated. Initially triggered by the collapse of the **US** housing bubble, the global crisis that followed was the result of a myriad of political and financial failings.

In the early 2000's, the intense competition between mortgage lenders to increase their revenue and maintain a healthy share of the housing market brought a time of easy credit conditions and a relaxation of underwriting standards. As a result the marketplace was awash with high-risk investments and excessive borrowing ~ giving rise to a number of hugely irresponsible practices by bond traders. This included selling *'sub-prime mortgages'* to borrowers who had no realistic chance of completing the repayments unless house prices continued to climb *(along with their equity)*. However when the property market collapsed, not only did it lead to a sharp rise in evictions, repossessions and unemployment, but few financial institutions remained unscathed. Many forms of predatory lending were now exposed ~ ultimately proving to be the undoing of numerous financial service companies. Indeed within the space of six months, dozens of banks, building societies, insurance corporations and mortgage lenders were either taken over, given emergency funding by their government, or bankrupted.

The bankruptcy of America's fourth-largest investment bank, ***'Lehman Brothers'*** was perhaps the most notable collapse to result from the sub-prime mortgage scandal. Other **US** casualties included savings banks such as ***'IndyMac'*** and ***'Washington Mutual'***, insurance corporations such as ***'AIG'***, and mortgage lenders such as ***'Fanny Mae'*** and ***'Freddie Mac'*** which were all subject to Federal takeovers. In fact, financial concerns all over the world were impacted by the crisis. In the **UK**, for example, established institutions such as ***'Northern Rock'***, ***Bradford & Bingley***, and ***'HBOS'*** were also either nationalised or taken over. Indeed as the recession started to bite over the following years, many hundreds of banks failed around the globe with American corporations alone losing over $8 trillion.

As if to emphasise the vulnerability of the global economy, every generation is faced with at least one serious financial crisis in their lifetime. The fact is that, throughout history, economic growth has not been not a smooth advance, rather an 'erratic cycle' of boom and bust in which *(generally speaking)* the rate and severity of economic decline correlates to the pace and foundation of growth in the period that preceded it.

Bringing the question of bank solvency sharply into focus, the 2008 financial crisis *(and subsequent recession)* had a huge impact on stock markets around the world. Yet it was effectively set up decades earlier, by the rise of free market politics in the late 20th century. The aggressive capitalism championed throughout the 1980's by the governments of **'Ronald Reagan'** in the **US** and **'Margaret Thatcher'** in the **UK** had brought hollow economic growth, and established a mindset of overindulgent financial greed. Elsewhere, the collapse of the 'Eastern Bloc' at the end of the decade, and the eventual break-up of the Soviet Union had brought a flood of money into the markets from wealthy Russian investors. Meanwhile, a new kind of *'clipped'* capitalism had developed from the policy of economic liberalisation in communist China. Bringing about a social and economic revolution, financial freedom here led to a gold rush mentality as millions of Chinese citizens now embraced Western ideals. By encouraging risky investments around the world, these major events lay the foundation for the global financial crisis that was to come. The spark would be provided by a new trend which had begun in the **US** ~ that of borrowing money against a mortgage in order to buy more real estate. Of course when the housing bubble eventually burst, the massive losses that would be incurred shook numerous institutions that were now built on unstable market assets.

Until the 'Great Recession' a vast majority of commercial assets that were purchased by financial institutions were themselves financed by debt. Central banks around the world encouraged property investors to borrow more and more ~ a policy that was ultimately unsustainable. However, this strategy benefited the wealthiest in society and fuelled a phenomenal growth in the financial sector. Indeed, although not so prevalent since 2008, *'mortgage-backed securities'* still remain a major profit centre for **US** banks. Of course, regulations are more stringent today, but the rapid rise in credit that was seen at the turn of the present century was reminiscent of the years leading up to the 'Great Depression' almost eighty years earlier. As credit rose so did corporate profit and, with most capital stock owned by a core number of shareholders, the distribution of wealth became increasingly polarised. So much so, that by 2000 the pattern of growth in the **US** had shifted to the point that the top 11% earners in the country were generating 99% of its income.

Whilst boosting economic growth, 'credit bubbles' also serve to exacerbate social inequality. When the economy is strong and people feel 'wealthier', more money is spent on goods and services *(often on credit)*. In times of strong growth, the financial sector is boosted even more than the rest of the economy, with the banks naturally profiting most of all. This has created a culture of massive incentives being offered to key management and staff within the banking sector. Indeed the individual bonuses that are received by some leading bankers are phenomenal, and are generally considered to be unjustified within the wider society. However the profits that 'investment banks', for example, can make during times of economic boom are simply staggering.

Since the **US** boom of the 1980's *(which saw the birth of the 'yuppie' and the rise of the 'nouveau riche')* social divisions along the lines of income and wealth have widened considerably. In the following decades, trillions of dollars of assets were acquired by the financial elite, perpetuating an asset-price battle that continues to this day. In the broadest terms, American capitalism by the 2000's had created a situation where the top echelons of society would freely lend money to the masses, but were wholly reluctant to raise their wages.

Financial prejudice runs deep in modern society, and the problems of the resulting social inequality were emphasised in the **US** by the policies of the ***'Federal Housing Administration' (FHA)***. Set up in 1934 to stabilise the American mortgage market, the **FHA** aimed to standardise home ownership, however its underwriting standards were highly discriminatory. Amounting to a form of environmental racism, the actions of the **FHA** *(up until 1969)* actually fermented urban decay, leading to the creation of deprived suburbs and ghettos. As a result, in multiethnic neighbourhoods, mortgage loans were much harder to get but, by the mid-1990's, they became flooded with credit. When the housing bubble grew at the turn of the century, there was an explosion in the numbers of people investing in property and, in areas that were historically 'run-down', mortgage securities were pooled by traders into risky investments that could be sold back to the markets. Of course when the housing bubble collapsed, debtors were stuck with 'worthless' properties that they could no longer afford, whilst numerous banks were left holding what became known as *'toxic assets'*.

Banks clearly make enormous profits at the expense of borrowers, but legislation to ban predatory lending was never passed into law in the **US**. Indeed investing money in consumer debt here was generally considered to be a better investment than any other. Illustrating the greed of capitalism, it is this mindset that made the global financial crisis of 2008 possible. On the eve of economic downturn, the property market was awash with sub-prime lending ~ sowing the seeds of the urban mortgage crisis to come. Indeed there was a lot of money to be made from refinancing mortgages to people who were likely to default on the repayments. Applications were even accepted from borrowers who were desperate just to avoid repossession! Besides making money on fees, lenders effectively stripped out the equity from such properties, and it was only a matter of time before many thousands of families would lose their homes.

As income levels failed to keep up with rising house prices in the years leading up to the Great Recession, borrowing against mortgaged properties increased greatly. This contributed to a vast redistribution of money that enabled the financial elite to become even wealthier. When house prices began to fall however, the days of '*making a killing'* in the housing market were over and the *'smart money'* moved into commodities, leaving the rest of society to suffer the consequences. The lowering of ratings on sub-prime mortgages had sparked panic and no one could sell after such a collapse of confidence, resulting in huge numbers of homeowners being left with negative equity. As recession bit, many small businesses faced insolvency ~ increasing unemployment and causing the cost of essential commodities such as food and fuel to rise. The illusory ideals of capitalism had, in essence decreased the standard of living for everyone except for the very top earners.

The immediate response by the American and European central banks to the sub-prime mortgage crisis was to purchase several trillion dollars of government debt and precarious bank assets. Having redirected hundreds of billions of dollars worth of public funds to 'bail out' numerous banks and financial institutions, government policy throughout much of the western world was to implement 'austerity measures'. Bringing an array of tax increases and spending cuts *(including reducing public services and cutting jobs)*, the policy of austerity made life even harder for the general populace ~ who effectively bore the brunt of the economic downturn. Yet austerity measures in the United States were wholly unnecessary because government debt is denominated in **US$** and the self-funded ***'Federal Reserve'*** could simply print more. Although in debt *(as of 2022)* to the tune of **US$**30 trillion, the world's richest country cannot possibly be bankrupted by dealings through the current global financial system. Indeed only destructive political wrangling can prevent the **US** government from making scheduled debt repayments.

In truth, the 'illusory' world of financial markets and capital venture can never be completely predicted or contained by even the most powerful institutions. Yet economics is the driving force behind modern civilisation, and it is ultimately at the mercy of nature. Although the global economy has largely recovered from the financial crisis that blighted modern society in the early 21st century, for how long it can continue to grow depends on the stresses we place upon the natural world and its increasingly scarce resources. In fact it is highly likely that a sudden failure of the markets and a complete economic meltdown throughout the world would precede the collapse of our Westernised civilisation. Such a financial catastrophe would be unprecedented ~ bringing mass unemployment, widespread anarchy, and eventually famine. Indeed for many *'end timers'*, a self-fulfilled prophesy of mankind's 'hell on Earth' would likely be realised.

Despite raising the prospect of such an undesirable future for humanity, almost every nation on Earth still prioritises economic growth over the well-being of the natural world. Indeed, in the name of progress, we continue to irrevocably change, damage and neglect the environment around us as we plunder countless delicate ecosystems for their valuable resources *(primarily for financial gain)*. So long as we remain more concerned with economy rather than ecology, our impact on the natural world will continue to grow, and modern civilisation's unquenchable thirst for energy will ultimately sow the seeds of its own collapse. The damage we cause by the extraction, refining and consumption of oil, for example, is incalculable yet, as the mainstay of modern civilisation, oil production is solely determined by economic output ~ with environmental consequences vastly underplayed.

A mentality of forsaking common sense and taking huge risks for 'profit' pervades the corporate mindset, with regulations designed to protect the environment from further exploitation or neglect continually being challenged by industry around the world. But it is not just the adverse environmental effects of widespread industrial activity that expose the fragility of modern civilisation. We live at a time when the natural world is being put under increasing stress as ever more of it is exploited to support *(and accommodate the demands of)* a massive, and continually growing, human population. As a result the price of essential foodstuffs *(such as grain, wheat, and maize)*, for example, continue to rise as fertile agricultural land is at a premium. This threatens the food security for billions of people *(particularly in the developing world)*, yet provides enormous profit for a comparatively small number of wealthy investors.

For most of the 20th century *(and beyond)* mankind was largely unaware of the extent to which we were damaging the environment, and the notion of anthropogenic 'climate change' did not even feature in our psyche. This left us free to pursue the uniquely human benefits of accruing material wealth *(and power)* without the unwelcome distraction of, for example, global warming. Today we are only too aware of the threat that it presents to both civilisation and the natural world *(despite the convenient scepticism of an ignorant minority)*. But for many successful investors, industrialists and politicians the current warming trend is regarded as little more than just that ~ a distraction. Alas our living planet is currently facing what is widely classed as its 'sixth mass extinction', but this time our own species are ultimately culpable. Yet still our nations focus on economic growth, whilst any meaningful action to protect the environment from further manmade destruction is wholly inadequate. Indeed, the greatest expense for many countries around the world is their 'defence budgets' which often dwarf the resources they set aside for environmental protection.

The fact that most countries around the world still invest so much more money into military research than into developing 'green technologies' is a long-term legacy of the Cold War. Alas, for many governments, the importance of national security is deemed far more critical than preserving the health of the natural ecosystems on which we and so many other species depend. Whilst our present inability *(or unwillingness)* to seriously tackle the greatest crisis mankind has ever faced is ultimately down to individual greed, it is our collective fear of other human beings that ensures the continued production and maintenance of costly weapon systems at the expense of so much. Indeed, even in the face of an impending environmental catastrophe, we are more concerned with the dangers we pose to one another than those that result from climate change and our ongoing desecration of the natural world. This mindset is well illustrated, for example, by the **UN** suspicion of Iran's nuclear ambitions in the early 21st century *(despite the country's insistence that its nuclear program was purely for peaceful means)*. The divisive stance of the 'Western World' was perhaps as much a reflection of its own collective morality as it was of its genuine fear of a nuclear armed Iran. Indeed it is 'western' distrust and suspicion that actually makes it more likely to compel so called *'rogue states'* to develop weapons of mass destruction in the first place.

iv.
(Intolerance and belligerence)

Throughout human history, a binding sense of kinship has existed between families of like-minded people who share common goals, have a common faith, and speak a common language. However, historically speaking, those on the 'outside' of an established culture are often distrusted, envied or just despised. Of course, in times of peace, social alliance and trade can create mutual prosperity *(to the benefit of all parties)*, but when strong disagreements manifest as profound cultural differences that cannot be resolved amicably, it invariably leads to violent conflict.

Whilst human conflict has occurred for hundreds of thousands of years, it is with the advent of *'behavioural modernity'* some 50,000 years ago, that it became organised ~ heralding the first tribal battles. It is only when early nomadic tribes began to settle in order to cultivate the land, that the value of ownership intensified the condition of human conflict. Indeed, with the onset of the *'Neolithic Revolution'* around 12,000 years ago, the number of sedentary communities rapidly increased bringing with it an almost continuous succession of wars.

As early human settlements grew, social organisation became increasingly complex, with scattered hamlets and villages giving rise to city states and eventually nations. Civilisation itself has been around *(in its many forms)* for over 6,500 years, with dominant cultures often subjugating and exploiting weaker communities that they come in to contact with ~ and with the birth of empire in the 3rd millennium **BCE**, the intensity and organisation of war increased dramatically. Warfare is the 'mother of invention', and by the time of the *'Industrial Age'* the most powerful empires and armies had developed highly efficient weapons that could kill their enemies in large numbers on the battlefield. Indeed the 20th century would become *(to date)* the most deadly in human history.

The 20th century also saw new heights of human endeavour ~ with enormous advances in the fields of science and technology. This unparalleled success in human achievement generated unprecedented material wealth and power, but with it came new low points for humanity. During the course of the century, the amount of destruction that a well equipped military force could wreak grew exponentially whilst, in terms of mass oppression and persecution, a new dark chapter had opened in human conflict. By now traditional seats of absolute power in the Western world *(namely the church and incumbent royal houses)* had been largely overthrown by political intrigue. Indeed, from the social upheavals of the previous couple of centuries, politics emerged as a way for people to direct the 'course' of their nation's *(and their own)* future prosperity. Ultimately it was regarded as a means through which societies could attempt to satisfy our growing desire as a species to attain the notional state of perpetual happiness. As a result, the 20th century saw a rash of countries become entrenched in dangerous political ideology that espoused intense national pride and a warped perception of Utopia.

Encompassing the two deadliest wars in human history *(as well as countless other calamitous regional conflicts)*, the 20th century illustrates the necessity of history for future human endeavour. If the abhorrent ideology of **'Adolf Hitler'** hadn't brought the world to war in the 1930's, for example, then the true horrors of fascism would not be known, and lessons would still to be learned. Indeed the existence of such a tyrant was necessary to adjust our collective perception of reality. In fact, it could be equally argued that if the ***'Nazi'*** regime had appeared at an earlier time in history, fewer lives would have been lost in the 20th century. Indeed, the history of civilisation is essentially the learning curve of a species that habitually explores every avenue of 'being' ~ leading to the rich and unquantifiable essence of the human experience.

The ***'Second World War'***, like the ***'Great War'*** before it, was a calamitous event in human history which cost tens of millions of lives. Alas, due to the persistence of negative human emotions such as hate and greed, neither would be the war to end all wars. Indeed human conflict will continue long after modern civilisation has collapsed. However, following the unconditional surrender of the *'Axis powers'* to the victorious *'Allied forces'* in 1945, the ***'United Nations'*** was formed, affirming a new world order *(dominated by liberal democracy and free enterprise)* that persists to this day.

Since the end of World War **II**, the globalisation of the modern world has continued at an ever faster rate ~ generating enormous wealth for millions of fortunate individuals around the planet. Yet, since its inception, the modern world *(with its strong democratic values and potent capitalist ideals)* has always been under intense pressure from outside forces.

The ***'Cold War'*** between the 'Western world' and the 'Communist Bloc' *(from 1947 to 1991)* represented the first big test for modern civilisation. In this new post-war atomic age, the political polarisation of former wartime allies dominated international affairs and, for over four decades, the modern world lived under the threat of mutual nuclear annihilation between two superpowers *(the **USA** in the west and the **USSR** in the east)*. Peaceful co-existence between the United States *(with its 'NATO' allies)* and the Soviet Union *(supported by its satellite states)* proved somewhat of a strain, with the citizens of both countries often subjected to partisan hysteria and the moral demonisation of its perceived enemy. Whilst the **US** and the Soviet Union never engaged directly in full-scale combat, every conceivable form of psychological warfare was considered in order to attack the interests of the other ~ with widespread espionage and other covert operations becoming the norm. Besides fighting regional 'proxy wars' with one another, the two superpowers embarked on an unprecedented arms race, engaging in dangerous nuclear brinkmanship. With patriotism positively encouraged, even sports that pitted the two nations against one another became the focus of something greater. Whilst victory in a big sporting occasion was readily interpreted as a form of social and ideological superiority, loss was often regarded with a degree of national humiliation.

In terms of living conditions for the ordinary 'working family' during the Cold War, life under the more oppressive Soviet regime was generally much harsher than it was under the freely-elected government of the United States. The whole mindset of the Russian population, for example, was vastly different ~ with the country's entire workforce striving for a planned economy, run by a state-controlled dictatorship. Without natural competition in the workplace, manufacturing industries here were hugely inefficient, entrepreneurial direction was stifled and enthusiasm was generally lacking. Indeed, for most people, job security was the single largest financial concern, with most families earning just enough to survive. In the **US** meantime, a capitalist mixed economy encouraged fresh ideas, with the most successful private companies continuously investing in new systems in order to maximise income and gain an edge over their competitors. Here, market forces catalysed technological advance, generating enormous wealth for the country and many of its citizens. Whilst union strength *(for the most part)* served to hold in the reigns of capitalist extravagance by helping to improve pay and working conditions, comparatively high taxes established government security ~ enabling the whole *'American Dream'* system to operate.

During the latter half of the 20th century, the liberal political tradition of North America and Western Europe became the accepted standard of a growing globalist culture. As a result, the more extreme nationalist ideals of many governments around the world were widely criticised. Nationalism became increasingly regarded as a dangerous force that could readily spark regional unrest and be the cause of major wars between otherwise peaceful neighbouring nation-states. Indeed, the idea that open liberal democracy underpins economic prosperity no doubt contributed to the fall of the last dictatorships in Southern Europe during the mid-1970's. From South America to South-east Asia, over the next couple of decades numerous governments with extreme nationalist agendas collapsed under the weight of capitalist democracy with its economic advantages and perceived humanist values.

In 1978 Chinese Premier **'Deng Xiaoping'** picked up on this liberating mindset, and broke from the communist tradition of ensuring complete state control over social and economic matters. By moderating the party's nationalist stance, Deng enabled The People's Republic of China to begin to catch up with the West technologically. A totally different kind of communist ideology to that of the Soviet Union, China adopted a *'socialist market economy'*, ~ a form of state capitalism which generated enormous wealth for the country. The ***'Chinese Communist Party'*** managed to assume tight political control, but now offered millions of people a new economic freedom. As a result of these reforms spending rose and consumer choice widened for growing number of people ~ encouraging a limited sense of individuality. Deng's modernisation programme even introduced bonus systems to encourage enthusiasm in the workplace. With news of an economic boom in the southern cities spreading to peasant villages throughout China, the country experienced the biggest ever peacetime migration of people. Indeed between 1978 and 2010 Chinese cities experienced an influx of over 250 million migrant workers.

In adopting a policy of economic liberalisation and exploiting its huge workforce, by the end of the 20th century China had the fastest growing economy in the world. Throughout the 1980's and 90's many international trade barriers had started to fall, but whilst the Chinese people were beginning to benefit from an explosion of private enterprise, the standard of life for millions of Russians continued to stagnate. In the **USSR** at this time a growing sense of humanity swept through the general population, with a number of its constituent states now hankering for greater autonomy whilst an aloof central government continued to spend more money on manufacturing of weapons of war than on the basic needs of its peoples.

The end of European communism as a credible state power began with its demise in Poland and Hungary. A watershed event however, was the symbolic collapse of the Berlin Wall in 1989 and the subsequent reunification of Germany as a single open democracy. Two years later the Soviet Union itself was dissolved, and for the first time in decades many peoples across Eastern Europe and Central Asia were given material, religious and nationalist freedoms.

Alas, with the break up of the Soviet Bloc in the early 90's, many parts of Eastern Europe saw a rise in nationalism, and nowhere was this more pronounced than in the former Yugoslavia ~ a conglomerate of six republics united as a single state under communist rule. Although it was not aligned to the ***'Warsaw Pact'***, Yugoslavia was already fracturing along the lines of its constituent republics when European communism collapsed ~ and rising separatism within now led to a series of violent ethnic wars.

Serbia *(the largest and most populous Yugoslav republic)* was home to the country's federal capital where the former communist regime retained power as the ***'Serbian Socialist Party'***. Naturally the authorities here were least willing to embrace true democratisation, and with many thousands of minority Serbs scattered throughout neighbouring republics that were now proclaiming independence from Belgrade, it embarked on an active policy of nationalist protectionism, The Yugoslav wars that followed were filled with xenophobic hatred, with the worst hostilities centring on Croatia and Bosnia/Herzegovina which had the greatest ethnic diversity. Old tensions between Serbs, Croats and Bosnians were once again ignited, and the war quickly descended into total chaos. Neighbours became enemies and, with both sides targeting civilians, countless major atrocities were committed.

Although the transition from communism to liberal democracy in most of the other Eastern European countries was comparatively smooth, the former Yugoslavia experienced depths of depravity not seen in Europe since the anti-Jewish pogroms some 50 years earlier. The Serb programme of 'ethnic cleansing' alone resulted in numerous war crimes, with concentration camps springing up where the summary execution of prisoners became commonplace. Whilst captured Bosnian women were subjected to systematic rape and horrific sexual violence, thousands of men and boys were massacred in their hundreds at machine gun posts ~ a pattern repeated later in the decade in Kosovo. Moreover extreme prejudices were inculcated in Bosnian-Serb children, many of whom were conditioned, for example, to believe in the cultural and ethnic inferiority of their Muslim Bosniak neighbours.

Yet the Yugoslav wars were just one of many horrific conflicts going on in the world at the end of the 20th century. Iraqi Kurds, Israeli Palestinians, and Chechens from the

Northern Caucuses for example, were all engaged in bloody conflicts for cultural, economic and political control of their regions. In Russia itself during this time, the democratic government of the new Russian Federation couldn't match the economic success of China and the West, and struggled to maintain the social fabric of the country. Besides dramatically reducing military spending throughout the 1990's, in order to survive the Russian government undertook a number of radical reforms that employed capitalist ideals. However a rapid privatisation programme simply passed the control of most state-run agencies to 'well connected' individuals ~ many of whom had held positions of high office during the Soviet era. A disastrous policy, it led to the creation of dozens of new billionaires almost overnight, of which most protected their wealth by moving a huge amount of money and assets out of Russia.

The rise of the Russian oligarch coincided with a major economic and social crisis within the country. Corruption was rife within the higher echelons of society, and often involved illegal deals and unregulated market trading. Meanwhile the gap between rich and poor widened considerably ~ with the collapse of social services and loss of many basic amenities sending millions of people into poverty. The streets of many Russian cities were once again burdened by a growing number of malnourished beggars, with up to 10,000 homeless children in Moscow alone. This was a period of both hyperinflation and growing lawlessness, where powerful criminal syndicates controlled a significant proportion of the country's internal markets. However, whilst mass corruption remains an endemic problem within many Russian institutions, at the start of the new century the nation had begun to recover ~ largely thanks to its new president, former **KGB** intelligence officer **'Vladimir Putin'**. As a result of Putin's *'strong arm'* policies *(both domestic and international)*, order and stability returned to Russia along with a new sense of national pride. Regional uprisings were emphatically crushed, whilst huge investment in commodities *(particularly within the energy industries)* helped to raise the standard of living. Of course, military spending rose sharply once again ~ as did old tensions between Russia and the West.

As the new millennium dawned, human conflict continued to bring untold suffering to many millions of people around the world. Indeed during the first decade of the 21st century numerous *'flashpoints'* would occur, emphasising the fragility of global peace. One hotspot for civil unrest was Kurdistan, a culturally-defined region of Upper Mesopotamia, that encompasses parts of Turkey, Syria, Iraq, Iran and Armenia. Numbering around 35 million people, the Kurds remain the largest ethnic population without their own state, and have endured cultural discrimination throughout the region for many years. This is particularly so in Southern Turkey, where approximately 14 million ethnic Kurds have no rights to a separate identity, and continuously poor treatment by successive Turkish governments prompted the resumption of armed activity in 2004. Fighters from the most prominent insurgent group, the ***'Kurdistan Workers Party' (KKP)***, now embarked on a period of sustained guerrilla warfare on the Turkish establishment. It marked the end of an uneasy ceasefire which had held since the **KKP**'s co-founder, **'Abdullah Öcalan'**, had been imprisoned under the threat of execution in 1999.

The sporadic rioting and frequent 'terrorist attacks' on the establishment in Southern Turkey throughout the decade were mirrored some 3500 miles away in Sri Lanka. Here the resumption of hostilities between the ***'Liberation Tigers of Tamil Eelam' (LTTE)*** and the Sri Lankan military from 2005 would add another 20,000 casualties to this long-running conflict. Before its ultimate defeat in 2009 the **LTTE** *(more commonly referred to as the* ***'Tamil Tigers')*** was a well-funded separatist movement that claimed to represent the entire Tamil community on the island *(a major ethnic group whose ancient lands spread throughout Southern India as well as the Northern and Eastern Provinces of Sri Lanka)*. However within its ranks was a violent militia whose activities ultimately brought enormous suffering to many communities in this small island country.

As the decade progressed, many other regional tensions around the world sporadically spilled over into civil unrest and violent conflict. Indeed, there was social upheaval as a direct result of human conflict on almost every continent. In South America, for example, the escalation of guerrilla warfare throughout much of rural Colombia was politically motivated, with attacks from various 'leftist' militias funded by criminal activity *(largely through the illicit trade in weapons and drugs)*. In Southern Asia meantime, demonstrations and riots continued throughout Jammu and Kashmir ~ a largely Indian-administered region containing a diverse patchwork of religious enclaves. Besides ongoing border disputes between India, China and Pakistan in the region, Kashmir is home to over 18 million people, with various separatist and nationalist organisations vying for control amongst its Muslim, Hindu, Sikh and Buddhist populations. Despite Pakistan's official withdrawal of military support for Muslim insurgent groups in 2002, tensions remain high, with the growing involvement of radical Islamist groups such as ***'Al-Qaeda'*** encouraging even greater militancy within the region. Indeed the ongoing situation in Kashmir has the potential to start a major military confrontation that could effect the entire world.

The continuing violence in Kashmir was never too far from the public psyche *(largely due to the nuclear capabilities of the countries in dispute)*, but numerous other conflicts around the world did not garnish so much media attention. There were a number of major conflicts in Northern Africa, for example, during the 2000's that were just as deadly. Indeed Algeria's vicious civil war was in full swing at the start of the decade and was followed, over the next few years, by disastrous conflicts that included violent insurgency in the Ogaden region of Ethiopia, and a bloody ethnic war in Darfur, Western Sudan.

Of course the most highly publicised wars during this time were ones that directly involved Western countries, as well as those whose battlegrounds were uncomfortably close to Europe itself. Whilst the West embarked on so-called *'wars against terrorism'* in Afghanistan *(2001-14)* and Iraq *(2003-11)*, Russia was involved in regional conflicts within and around its own borders. Not only was it fighting almost a decade of insurgency in Chechnya *(2000-9)*, but in the Southern Caucasus it now occupied the South Ossetia region of neighbouring Georgia *(in 2008)* ~ aiding insurgents here and escalating the conflict, before unilaterally recognising its independence.

Many more conflicts would erupt around the world during the 2010s, and the involvement of Russia in the most infamous of these was significant. In 2014, following a pro-Western revolution in Kyiv, Russia's historic ties with Ukraine were considerably weakened ~ prompting it to annex the Crimean peninsula, and covertly support separatist uprisings in the east of the country. Indeed, the continuing presence of well-armed pro-Russian militia in the Donbas region of eastern Ukraine led to military stalemate here, bringing about a *'frozen-conflict'* with the Ukrainian government that claimed the lives of thousands of civilians. However, until Russia's reckless invasion of Ukraine in 2022, the violent disruption in Eastern Europe was relatively mild compared to the myriad of conflicts that would blow up in North Africa and the Middle East during the 2010s as a result of the failure of the so-called ***'Arab Spring'***. What started as a 'somewhat hopeful' route to peaceful democratisation within the Arab World in 2011, ended in some of the most bloody and violent conflicts in modern history.

The most recent upheavals within the Arab World began somewhat inauspiciously with a campaign of civil resistance in Tunisia ~ sparked by the self-immolation of a persecuted street vendor in 2010. After years of high unemployment and political repression here, the growing social unrest that followed ultimately led to the overthrow of a corrupt authoritarian regime and brought about serious parliamentary reform. The successful Tunisian Revolution inspired similar protests in a number of other ***'Arab League'*** states ~ spreading rapidly with the help of social media. However, although having varying degrees of mild success in places such as Algeria, Morocco, Oman and Jordan, elsewhere demonstrations were met with a decisive and often violent response from the authorities ~ with events developing into series of complex crises in various countries within the region. The consequences of failed uprisings were often brutal and, within a couple of years, the original spirit of the Arab Spring had been completely lost.

One important factor in the success of the Tunisian Revolution was a resulting constitution which rejected Sharia law and reinforced the country's secular identity. However in Egypt, for example, the uprisings prompted political instability, with the struggle between Islamist and secular forces bringing about the overthrow of successive governments. Following a coup d'état in 2013 which removed the ruling ***'Muslim Brotherhood'*** from power, the widespread persecution of political activists and subsequent mass trials only served to inflame unrest within an increasingly fractured Egyptian society. The ultimate failure of the Arab Spring in Egypt resulted in continuing instability, whilst the rise of Islamist movements here and throughout the wider Arab World has led to a significant increase in armed insurgency.

Although both Egypt's economic health and sense of national security have suffered considerably in the aftermath of the Arab Spring, it has been comparatively fortunate. Elsewhere, government attempts to put down the initial demonstrations in 2011 turned protest into armed revolution, with the situation often escalating into ferocious civil war. The resulting power struggles have brought misery to many millions of people in countries such as Libya, Yemen, Iraq and, of course, Syria where the ongoing war has killed over 200,000 people. Here, the spread of violent insurgent groups *(some intent on genocidal control)* has led to the complete destruction of entire communities, and, with the Syrian government treating all who oppose it as terrorists, what are generally considered as 'acceptable rules of engagement' by the international community simply do not apply.

Alas, by the start of the present century the Arab World had become a region beset by deepening troubles. The failure to restore peace after the invasion of Iraq by the United States and its allies in 2003, and an ill-conceived **NATO** intervention in Libyan affairs in 2011 provoked an increase in both anti-Western sentiment and Islamic extremism. Rather than help the plight of 'moderate' civilians and encourage the creation of open democratic societies, foreign involvement deepened a number of crises in the Arab World. Indeed in a little over two years after the unrest in Syria had escalated into all-out civil war, the conflict had drawn in a number of neighbouring Arab states as well as various outside forces with different ambitions and objectives. A hugely complex situation, the ongoing conflict in Syria threatens to become a direct proxy war between the United States who strongly oppose the Syrian government, and Russia ~ the regime's most powerful ally.

Other than countries that are involved from the outset *(either directly or otherwise)*, the international community as a whole is generally slow to react to regional foreign conflict ~ especially with regards to the supply of humanitarian aid. Indeed, unless they have a vested interest in the outcome, the involvement of most foreign powers in catastrophic civil wars has lessened considerably since World War **II**. In the immediate post-war decades, old 'Cold War' foes were eager to come to the aid of their respective 'allies', with wars in Korea, Vietnam and Cambodia, for example, fought with the unquestioned backing of major world powers. In later decades however, the willingness to get involved *(even when faced with evidence of serious atrocities)* started to diminish. It took 8 months, for example, for the '**UN**' and '**NATO**' to act following the start of war in Kosovo in 1998, despite evidence of systematic genocide here. Alas the aggressive policies of Yugoslavian president **'Slobodan Milosevic'** led to many thousands of Kosovan Albanians being massacred, and threatened to wipe out an entire culture before the moral drive to oppose him militarily was eventually galvanised.

By the time that the Syrian War had broken out in 2011, there was even less desire by the West to get involved. Indeed it took over three years before any nation outside of the Arab world intervened militarily to protect embattled civilian populations. The **US** and many of its allies had become *'war weary'* after serious mistakes in the conflicts of Iraq and Libya had turned public opinion firmly against military intervention. Not wanting to get embroiled in another convoluted Middle East war that could lead to the unnecessary deaths of yet more troops abroad *(a sure-fire vote-loser)*, most leading Western politicians were unwilling sanction their country's intervention in the Syrian conflict.

With a sense of altruistic intent however, by 2014, the West finally did get involved ~ initially non-militarily, through the supply of logistics and training for the short-lived ***'Free Syrian Army'***. This was followed by limited air strikes in support of local militia fighting Islamist extremists *(primarily the self-declared **'Islamic State' [IS]**)*. However, just over a year later *(having finally shrugged off the humiliation of the* *protracted Soviet-Afghan War from the national psyche)*, Russia also intervened, this time in support of the beleaguered Syrian authorities. Concerted Russian air strikes against any force that was hostile to the Syrian government further changed the dynamics of this horrific conflict.

Highly unlikely to have retained power without Russian assistance, the brutal dictatorial regime of Syrian President **'Bashar al-Assad'** now fought rebel forces with greater resolve. Paying no regard to large civilian populations, both Russia and Syria now carried out the indiscriminate bombing of regions not under government control ~ targeting both extreme Jihadist groups and 'more moderate' anti-government factions of the ***'Southern Front'*** supported by the West. For the first time since the end of the Cold War, the 'conflict of interest' between the American and Russian armed forces threatened to destabilise the wider peace.

The ferocious civil war in Syria exposed new depths of inhumanity ~ becoming the most brutal and unforgiving of all conflicts since 'World War **II**'. A complex mix of religious and ethnic hatred made sure that established conventions of warfare were completely ignored by most antagonists. Besides the widespread use of torture on civilians and combatants alike, the Syrian War has seen mass public executions and persistent suicide attacks by Islamic extremists. Belligerents on all sides have been accused of using chemical weapons against their enemies, whilst the use of cluster bombs and thermobaric explosives in rebel-held areas by the Syrian and Russian air forces has been without restraint. Indeed, even schools and hospitals are considered legitimate targets *(albeit privately)*. Yet, contrasting with the hateful intention of the Syrian government and its enemies, involvement in the war by the West is largely driven by perceived humanitarian obligations.

The Syrian Civil War *(like countless others before it)* has seen concerted attempts by some belligerents to wipe out the cultural identities of entire peoples. Whilst a number of Shia, Christian, and Druze communities have been decimated by the Syrian war, particularly disturbing are the genocidal **IS** attacks on ***'Yazidi'*** towns in both Syria and Iraq. Indeed it was the plight of the Yazidis in the Sinjar region of Northern Iraq that initially prompted the United States to carry out air strikes on **IS**.

A Kurdish ethno-religious group indigenous to northern Mesopotamia, the Yazidi people have suffered enormously during the civil wars in Syria and Iraq ~ with concerted attempts by **IS** to completely eradicate their culture. As a way of life that's developed over hundreds of generations, it is our culture that essentially makes us who we are. Our ideas, customs, social behaviours and belief systems are all intrinsic to our cultural identity. So whenever an entire community is attacked and their cultural heritage violently repressed during a regional war, most people living elsewhere in the world are appalled. Indeed it is the natural inclination of a vast majority of *'free-thinking Westerners'* to feel morally repulsed by such a notion. But over the past few centuries, Western culture itself has overrun *(initially by force)* and suffocated countless other native cultures around the world, so it's unsurprising that outside of Europe, and North America the 'primarily philanthropic' motives of Western countries when participating in regional wars today are generally treated with suspicion. In the case of the Yugoslav wars, for example, the West *(as **NATO**)* felt a moral duty to intervene on humanitarian grounds, whilst countries such as China and India *(whose people have been historically persecuted by Western forces)* were firmly against intervention. Most Russians meanwhile considered Serbian fighters to be brothers in arms, but at the end of the 20th century Russia was in no position to prevent military involvement by the West. A similar pattern of alignment between East and West emerged during the Syrian Civil War, with the leaders of some nation states unable to perceive the same moral justification for involvement that most Westerners could see. Always suspicious of Western intent, both Russia and China however are far stronger *(and more belligerent)* than they were in the 1990's.

By the early 2020's these two huge military powers were engaging in numerous illiberal activities both within their borders and elsewhere around the world. China under **'Xi Jinping'**, for example, was forcibly imposing its rule on Hong Kong in breach of international agreements, whilst building military outposts in the South China Sea to control key shipping lanes the region, and discreetly attempting to eradicate the entire Uyghur culture from its northwestern provinces. Meantime, Russia under' **Vladimir Putin'** was engaging in several vicious conflicts in Syria, the Central African Republic and, of course, Ukraine, which has brought the world closer to war than at anytime since 1945.

It is clear that whenever there is serious international disagreement over matters such as a major regional conflict, tensions between East and West rise, with Russia and the **US** invariably on opposite sides. Old feelings of mutual mistrust resurface, with the media *(particularly in non-Western countries)* often awash with emotive reports that emphasise the anger and nervousness of politicians and military leaders ~ occasionally prompting talk of escalation towards *'Armageddon'*. Whilst such extreme claims are usually no more than sensationalist scaremongering, regional wars such as those in Syria, Libya, Iraq and Yemen during the 2010's and 20's do tend to further open the schism between major world powers *(notably the **US**, Russia and China)* whose foreign policies concerning various other regional 'hotspots' *(such as Iran, North Korea and Israel)* already differ considerably. Moreover, devastating civil wars can also provide a distraction, allowing dictatorial leaders elsewhere in the world to seize opportunities and take military actions that might otherwise prompt serious international condemnation. Ultimately, they have the potential to incite the breakdown of international law and even destabilise the current world order.

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For many decades after World War **II**, ***'liberal democracy'*** *(a pillar of Western culture)* served to prevent the more extreme political ideologies and ambitions from again being realised in the developed world. Indeed, right up until the mid-2010s, the open democracies adopted by almost all post-industrial capitalist economies created political balance. In a majority of countries within North America, Western Europe and Australasia, for example, power was *(and largely continues to be)* entrusted to elected representatives who owed their temporary governance to the *'majority vote'* of a fully enfranchised populace. Over time however this unique form of modern *'Western-style'* democracy, bred widespread apathy and disillusionment as successive governments invariably failed to live up to voter expectations. With a growing sense of social inequality permeating the cultures of many Western countries *(not helped by an almost continuous feed of scandals involving corruption, sexual impropriety and shameless privilege within mainstream politics)*, the fabric of liberal democracy itself would be threatened by the *'protest vote'*. Galvanised by a perceived failure of the political system and empowered by the Internet revolution, a plethora of non-mainstream political parties gained popularity in numerous Western countries. By 2016, the wealth of misinformation, half-truths and unscientific conjectures largely spread by digital communication caused disgruntled voters *(initially in English-speaking democracies)* to turn the 'marginal policies' of various protest movements into reality.

Since the middle of the 20th century, the path of governance within most open modern democracies has been without a sustained purposeful direction. Indeed for many decades the governance of most Western nations has continued to move back and forth between the political left and right, with each newly elected government facing new challenges to resolve in a world that is technologically more advanced than the last time that their party was in power. Meantime the policies *(and sometimes the entire philosophy)* of a losing political party are adjusted according to its perception of public opinion. This can lead to the formation of fresh ideas or the evolution of 'established party policies' towards an increasingly extreme ideology. That's the dynamism and danger of modern liberal democracy.

Alas, the progression of perceived atonement by political movements that have returned to power after a prolonged absence has ultimately made the governments of many Western nations increasingly susceptible to making ill-founded or misjudged decisions based on populist beliefs *(particularly when confronted by potential involvement in unexpected or unpredictable events such as war)*. In general, Western politicians will pander to public demands if they believe that it will advance their wealth, career, or sphere of influence. This is especially apparent when political debate concerns matters of national security. One example of this has manifest as a broad shift in the American psyche at the start of the 21st century, where the perceived threat of Communism from within the United States was replaced by one from Islam *(despite the more pressing issue of rising Christian fundamentalism within its own borders)*. From this and countless other historic socio-political events, it is clear that power can corrupt our collective perception of ***'factual evidence'***, and what constitutes ***'the truth'***. Indeed, not unlike the officials of 'single party' dictatorial regimes, many ruling politicians within capitalist societies *(such as the **US** and most other Western democracies)* attempt to retain political power at all costs ~ with little respect for morality in private, but with the façade of a 'caring' public persona. The only difference is that in liberal democracies, government is ultimately answerable to its citizens, rather than the other way around.

A vast majority of people in the developed world are very fortunate to be living in an open society with high regard for upholding civil liberties. Alas, however, the political system here is ultimately 'self-corruptive' and, towards the end of 20th century, the many frailties of Western-style liberal democracy had started to become evident. This was especially noticeable in the **USA** where the political establishment was clearly 'rotting' from within. By the 1980's, for example, showmanship had become a major element of American politics ~ allowing successful candidates to peddle policies that, in themselves, were not vote winners. Particularly prevalent was the exploitation of 'celebrity' ~ the appeal of which won numerous elections. Examples include former actors such as **'Clint Eastwood'** *(mayor of Carmel 1986-88)*, **'Arnold Schwarzenegger'** *(Governor of California 2003-11)* and of course **'Ronald Reagan'** *(**US** president 1981-89)*. The combination of 'fame' and 'novelty' also began to be used to great effect in American politics from this time. The political campaign of ex-professional wrestler **'Jesse Ventura'** *(governor of Minnesota 1999-2003)*, for example, was notable for the marketing of children's dolls in his image *(as a suited politician ready to wrestle his opponents to defeat)* ~ just one of many inane ways that would be used by numerous politicians to win over the American electorate.

The questionable dignity of political life in the **US** is not restricted to the campaign trail. Indeed, once in office, the behaviour of many politicians and civil servants has belied the importance of their role as representatives of the American people. In all echelons of government, countless officials have taken advantage of their positions to serve their self-interest; an unfortunate certitude that has even effected the highest seat of power ~ the presidency itself. The corrupt nature of **'Richard Nixon'**s presidency *(1969-74)* for example, was revealed through the ***'Watergate scandal'*** whilst, more recently, the otherwise successful tenure of **'Bill Clinton'** *(1993-2001)* was seriously marred by revelations of a sexual affair *(the **'Lewinsky scandal'**)* and his subsequent testimony to the contrary.

The actions of Clinton *(like those of Nixon before)* had a profound effect on the course of American politics. Having been impeached and narrowly acquitted over perjury and obstructing the course of justice, Clinton's eventual admission of misconduct *(following repeated denials)* only came when evidence of sexual impropriety 'stacked up' against him. However, in order to avoid conviction and the possibility of further criminal indictment, Clinton successfully argued that he did not use his position to force witnesses to lie under oath. Despite maintaining his popularity, the impact that his extramarital affair had on the political establishment was considerable, with the integrity and moral character of presidential candidates during the next **US** election coming under immense scrutiny. Indeed the unpalatable notion of sleaze within public office prompted a political backlash and a wave of support for the moralistic 'right'. How could the American people possibly trust a man with access the 'nuclear codes', but could not trust him to overcome his own sexual urges? This pervading concern resulted in the most tightly contested election in **US** history, and the inauguration of a president who would unwittingly provoke even greater distrust in the American political establishment.

Despite the high popularity of the outgoing Democratic president, the start of the 21st century saw the political landscape of the **US** alter considerably with the election of Republican **'George W. Bush'** *(2001-9)*. In terms of health and social reform, the new administration was seen to be more inclined to uphold traditional *(Christian)* American family values, whilst its economic policies were geared towards industry, often at the expense of the environment. As the eldest son of 41st president **'George H.W. Bush'** *(Clinton's predecessor),* the conservative policies *(both domestic and foreign)* of the two Bush presidents bore many similarities. Alas, the international events that would unfold during George Bush junior's presidency would shape his unfortunate legacy. The misjudged military operations that he sanctioned in the wake of the ***'September 11 attacks'*** aspired *(largely unsuccessfully)* to emulate the earlier successes during his father's presidency. Indeed the **US** invasion of Afghanistan in 2001 marked the beginning of Bush's so-called *'war on terror'* ~ a policy that initiated a protracted **NATO** presence in the region, and which would ultimately prove hugely damaging to international security.

The eagerness of the Bush government to use **US** military might was primarily based on an emotional response *(namely swift retribution for terrorist attacks on American soil)* rather than to achieve long-term strategic success. Alas the irresponsible decision by Bush to attack Iraq in 2003 *(after naming it as part of his 'axis of evil')* was matched only by the economic failings of his administration.

Throughout most of Bush's term in office, the world economy was buoyant, and the American technology industry was booming. Advances in computing during this time opened up a wealth of global information to many millions of people, with access to the Internet providing instant communication links around the world. This naturally led to the creation of new jobs, but whilst employment was widespread in the mid-2000's, it was largely without adequate protection. Economic growth in the **US** prior to the ***'sub-prime mortgage crisis'*** in 2008 was consequently very fragile, with rapid shifts in fortune leading to an increasingly unstable economy. This was a time of unbounded capitalism, when the generation of new wealth accentuated the growing gulf between extravagance and poverty, both in America and the wider world. Whilst the poorest in society were seeing few benefits but facing greater uncertainty, the richest were getting richer ~ a trend mirrored to differing degrees around the world *(particularly so in China and Russia)*.

Riding on the back of a hollow economic boom *(that relied heavily on consumer borrowing)*, Bush secured re-election in 2004, but his second term would prove disastrous. His administration's slow response to the ***'Hurricane Katrina'*** disaster in 2005, seriously damaged his public image as a caring president, but it was the ***'global financial crisis'*** three years later *(from which millions of Americans suffered)* that ultimately ended the Republican grip on power. Not only did it reveal the true nature of corporate greed, but it exposed government disregard for *(or even endorsement of)* unethical practices by American financial institutions ~ tainting the Bush administration with more than just an air of hypocrisy.

During George Bush Jr.'s presidency, the **US** government was complicit in perpetuating a raft of immoral practices that amounted to 'state corruption'. Indeed there was collusion between various government departments to obstruct the course of justice, and even subvert elements of the American constitution. By the time of the 2008 election, justice and propriety was felt to be lacking in both corporate America and the federal government, and the moralistic policies of Bush no longer resonated with the masses ~ resulting in the election of a far more liberal administration.

Under Democrat **'Barack Obama'** *(2009-17)* the **US** began its slow economic recovery, however the election of its first African-American president would ironically be a catalyst for the growing partisan divide within the country. Although receiving the highest approval rating of any American president outside of the **USA**, at home the Obama administration was increasingly seen as being ineffectual. With his domestic policies *(regardless of intent)* obstructed at every opportunity by an overtly hostile Republican opposition, Obama's efforts to improve the welfare of the American people were ultimately frustrated by his political opponents. From *'health care reform'* to *'gun control'*, Obama faced uncompromising political resistance which, over the course of his presidency, eroded the high expectations that had accompanied his inauguration. By the end of his second term in office, Obama's opponents had begun to capitalise on a perceived failure of the president to get to grips with an array of 'important issues'.

There has been a growing trend in recent decades for mainstream opposition parties throughout the Western world to adopt 'often divisive' new policies in order to galvanise support from disaffected voters ~ most of whom feel a need to rebel against the incumbent political establishment. In almost all cases, the forces that have shaped these new political landscapes are fuelled by emotive opinion rather than objective facts. The problems are compounded by the shallow nature of modern political life, with a growing number of career politicians abandoning previously held principles simply to appeal to the popular vote. This phenomenon has strengthened the hand of influential populist movements whose 'fringe policies' can gain considerable support within opposition parties that are actively seeking a return to power. In the case of the Republicans, during Obama's eight year term, new populist agendas arose from the birth of the ***'Tea Party movement'*** ~ a loose affiliation of ultraconservative political activists.

The fractious nature of the Republican Party throughout its time in opposition during the Obama presidency allowed populist movements *(such as the Tea Party)* to gain considerable political traction. The absurd conclusion of this was the eventual nomination of maverick billionaire and reality **TV** personality, **'Donald Trump'**, whose successful campaign in 2016 made him the most unlikely president in American history. Both a master of spin and a pathological liar, the election of Trump *(2017-2020)* was a slap in the face for Western democracy, and emphasised just how dangerous the growing polarisation of politics *(like that of religion)* in America had become.

Trump's self-branded style of politics was a perfect fit for the growing disaffection felt amongst conservative Christian voters throughout middle America. Although many of his popularist policies were ill-conceived and without real substance, his campaign promise to *"make America great again"* appealed to many millions of voters. Provocative and outwardly passionate, he was adept at telling his supporters exactly what they wanted to hear. However, although he stumbled throughout, Trump's election campaign was actually a masterful display of public manipulation which preyed upon the fear and ignorance of people. With his blinkered *(and highly inaccurate)* appraisal of what's wrong with America and the world, Trump claimed to have all the answers, and proffered protectionist policies grounded on the distrust of anything perceived as being un-American.

Promoting himself as a hugely successful patriot, Trump promised to employ his smart business acumen to run the country should he become elected. Yet Trump's attacks on his political enemies, and his retorts to those who publicly opposed his ideas during his presidential campaign were more childish than businesslike. Moreover, he was even unaccepting of established facts if they didn't suit his cause, and made numerous outlandish claims whilst running for the presidency ~ often citing a biased media for distorting the truth. In reality, Trump himself was guilty of promoting blatant untruths and perpetuating myths in order to further his own political ambition. Since 2011, for example, he had consistently questioned Barak Obama's American birthright and therefore his presidential validity, only to publicly relinquish the claim in the face of overwhelming evidence just two months before the 2016 election.

With undertones of racial prejudice *(the building of a Mexican border wall)*, or anti-Muslim rhetoric *(such as the banning of all Syrian refugees)* Trump's key policies on homeland security purported to protect the **US** from international terrorists and criminals. However their most pronounced effect would actually be to increase racial tension both at home and abroad. Like his divisive foreign policies, Trump's promise to radically boost the American economy was also based on unrealistic ideas that appealed to vast swathes of disaffected Republican voters in middle America. So powerful was his promise to overhaul the federal government by *'draining the swamp'* in Washington, that his supporters readily excused his own many transgressions *(for which he often remained defiant and unrepentant)*. Indeed Trump effectively changed the face of political etiquette in America.

Despite generating huge disdain for his character amongst more liberal voters, Trump's wrong-doings *(as socially and politically unacceptable as they were)* were no longer punished with the same severity that befell political scandals of old. Despite making misogynistic remarks and exhibiting blatant sexism, his campaign trail could not be derailed. Even the release of a tape that exposed his derogatory attitude towards women, and his unfortunate public ridicule of a disabled reporter failed to stop his ascendancy to the **US** presidency *(with or without the help of Russia)*. What started out as little more than an audacious ego trip, Donald Trump's successful ambition to become America's 45th president would ultimately prove disastrous for both the United States and the wider world.

Posing a significant threat to both international security and the world economy, the rise of Trump was made possible by tapping into a groundswell of political disaffection and exploiting the growing distrust *(and dislike)* of mainstream politicians. This emotive, anti-establishment sentiment felt by many American voters at the 2016 election had surfaced some four-and-a-half months earlier in the United Kingdom where a referendum on its continued membership of the ***'European Union'*** turned up a largely unexpected result. Here, the decision to leave the **EU** *(or initiate **'Brexit'**)* partially resulted from a sense of great unfairness in the policies of the European Parliament *(as well as the seemingly disproportionate cost of Britain's continued membership)*. This perception was capitalised on by politicians who were able to sell their delusional belief that the **UK** could actually benefit from relinquishing its **EU** membership, through fierce campaign strategies which often promoted inaccurate claims based on bias research. Indeed, despite the clear advantage of participating in an alliance of neighbouring countries *(which together form a single free trade market and the world's second largest economy)*, a vast swathe of the British public were convinced that it would be somehow beneficial for the **UK** to lose whatever influence it had within the union in favour of *'taking back control from Brussels'* and building new trading partnerships. With the comparatively tame *'remain campaign'* relying heavily on 'scaremongering tactics' and consisting of unpopular mainstream politicians from across the political spectrum, the scene for an unlikely protest victory was set. Ultimately however, the proposed economic merits of either leaving the **EU** or remaining within it was, for many disillusioned voters, a secondary consideration. Ironically, in what is one of the world's most liberal and open multicultural societies of all, the decision to leave the **EU** was largely founded in an irrational fear of immigration. This, despite the fact that Britain's rich cultural diversity only exists because of the successful integration of immigrants into its society for well over a century.

Announced by the incumbent British prime minister **'David Cameron'** *(2010-16)*, the referendum on **EU** membership *(like Trump's election victory a few months later)* would prove to be highly divisive. It was organised primarily for political gain, with Cameron *(a prominent 'remain' campaigner)* agreeing to such a referendum in order to appease the *'Eurosceptics'* within his own party. His political gamble however failed, and his decision to hold the referendum would completely alter the course of Britain's economic dependency for many years to come. Furthermore, the narrow margin of victory for the 'leave' campaign exposed regional divisions as England and Wales *(but not London and Cardiff)* largely voted to leave the **EU** whilst Scotland and Northern Ireland predominantly voted to remain. Re-igniting the desire for Scottish independence and re-exposing the partisan rifts in Northern Ireland, the decision to withdraw from the European Union, will not just precipitate the eventual break up of the United Kingdom, but will compromise the security of Europe as a whole ~ seriously weakening the progressive nature of the social, political and economic unity that has been forged there since the end of the Second World War.

With the vote for 'Brexit' becoming a portent of things to come, the political ascension of Donald Trump to the American presidency heralded what has been referred to as the *'Post-truth'* era. Of course numerous regimes throughout the ages have been guilty of distorting the truth and attempting to rewrite history in order to consolidate power or justify their aims. But today, thanks to the power of modern digital communication, people with the ability to exploit social media are able to magnify the scale of deception to the point that falsehoods can gain greater global exposure than the facts that they belie. An art not lost on other world leaders *(including **'Vladimir Putin'** and **'Xi Jinping'**),* the Trump administration, since its earliest days in office, attempted to manipulate established facts into 'believable alternatives' that were often based on conjecture, myth, or prejudice as a way of normalising its radical conservative agenda. Trump's election victory in America irrevocably changed the political landscape, consuming modern liberal democracy *(and its self-assumed ideological supremacy)* into a new world where even outright lies could be used to justify the merits of ill-conceived policies.

This political trend will continue to gain traction across the democratic world so long as there are unscrupulous politicians who can tap into the *'us and them'* mentality and appeal to the sense of unfairness, distrust and imposition brought about by decades of globalisation. It has given rise to right-wing popularist movements in many parts of Europe during the late 2010s, with France, the Netherlands and even Germany witnessing a rise in nationalist sentiment. Whilst the dream to build an open and benign Europe based on political and economic union is under increasing threat from unsavoury activism, the **US** has also had to endure the growing activity of numerous so-called *'alt-right'* movements that have been emboldened by Trump's success. The rise here, and across the world, of deeply partisan politics can only lead to more hate and distrust between rival groups, and so increase the likelihood of conflict and war. Surely the best hope for the future of humanity lies in removing barriers, and encouraging mutual co-operation, rather than building more walls and attempting to isolate ourselves from perceived enemies?

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The modern global civilisation that supports us today is by far the most successful civilisation that humankind has ever created. Dominated by liberal democracies that have largely adopted a *'Westernised culture'*, most modern societies rely on a national constitution that enshrines values which protect the freedom and liberty of their people. Moreover, Westernised nations are served by democratically elected governments and most have credible judicial systems that strive to be fair and just. A vast majority people living in the Western world have open access to public institutions such as schools and hospitals, whilst basic necessities are *(for the most part)* easily affordable. Indeed there are comparatively few people living in the absolute privation that is often endured by over five billion people who suffer existence within poorer *'underdeveloped'* regions of the world.

The dominance of developed nations is down to the wealth that they have accrued over the past few centuries *(often through exploiting the natural resources of far-away lands and seas)*. Today, most liberal democracies are held together by huge economies that are powered by a variety of successful capitalist ventures. Indeed Western economies continue to generate vast material wealth and, as a result of continued globalisation, today almost two billion people worldwide enjoy the benefits of living in the modern world. However, Western culture, is coming under increasing pressure from an array of forces which could readily expose the political and economic fragility of modern civilisation.

Whilst the process of globalisation continues unabated, there are numerous forces at work contributing to the erosion of civilisation in its present form. Our modern westernised lifestyle, for example, is not energy efficient ~ it is costly to maintain and hugely damaging to the environment. Other challenges that face modern society include dwindling resources and overpopulation, but equally troubling are conscious attempts to destroy it or manipulate the values that hold it together. Indeed the 'West' faces a concerted effort, from an array of foreign aggressors prepared to weaken its foundations and bring it down ~ be they ideological attacks from countries that have developed an anti-Western sentiment because of its colonial past, or terrorist organisations that hold a deep hatred of everything associated with the modern world *(except, of course, for weapons).*

Perhaps the most evident example of anti-Western sentiment is the steady rise of Islamic fundamentalism, in particular the self-proclaimed ***'Islamic State'*** which, since its initial emergence as a militant jihadist group in 1999, has proved highly resilient. But, whilst our 'civilised' way of life is under threat from an array of forces across the globe, it is also being attacked from within. Nowhere is this more evident than in the United States ~ a nation considered to be at the heart of the democratic *'free world'*, and one with strong Western ideals. Yet the **USA**, despite championing fundamental civil liberties, has a long history of prejudice, and institutionalised racism is ingrained within American society. Indeed since emerging in 1865 from a dark era of legalised slavery which had lasted for over two hundred years, the **US** has struggled to eradicate violent discrimination from within its own borders.

Whilst many American politicians have become obsessed with Islamic fundamentalism in the early 21st century, the greatest terrorist threat to the country actually comes from extreme right-wing groups ~ many of which have a warped Christian affiliation. Indeed steady growth of neo-Nazi and white separatist organisations in the **US** since the 1970's has been staggering and highlights the fragility of Western democracy.

One of the most destructive forces, with this regard, is a work of fiction entitled ***'The Turner Diaries'*** which was written by political activist and white supremacist **'William Luther Pierce'**. 'Indeed, 'The Turner Diaries' has provided inspiration for numerous far-right organisations since it was originally published in 1978. It depicts a full-blown race war that begins with civil conflict in the **US** and ends in the annihilation of all 'non-white people' across the world. Revelling in nuclear, chemical and biological attacks on the enemies of white America, the story describes a post-apocalyptic world that is finally at peace under a benevolent white rule. Classified in some countries as *'hate propaganda literature'*, 'The Turner Diaries' is a fantasy that many far-right fanatics desire for reality, whilst Pierce himself believed that *'one day 'white people will retake America by force'*. With a deep hatred of multiculturalism, Pierce saw himself as a racial patriot and, in his final years, regularly used the Internet to spread his anti-Semitic views.

Pierce's vision of the American future was the antithesis to that of the nation's most celebrated civil rights activist **'Martin Luther King Jr.'** Indeed The Turner Diaries' provided a blueprint for numerous far right movements whose aims, if achieved, would bring about the total breakdown of today's liberal, democratic society in America. The subtle beginnings of this wider goal was to ensure that mainstream politicians with extremist sympathies were elected ~ in order to sway the balance of political power. In this way, people's perception of fascism could be slowly desensitised, and accepted ideals could become increasingly more extreme.

Having founded the white supremacist movement ***'National Alliance'*** in 1974, Pierce's ideological ambitions *(as set out in the Turner Diaries)* were not too dissimilar to those of right-wing activist **'George Rockwell'**, founder of the infamous

'American Nazi Party' *(ANP)* in 1959. An organisation based on the ideals and policies of **'Adolf Hitler'**, the **ANP** promoted the belief that Jews were causing a breakdown in American society, that African-Americans were psychologically inferior to white Americans, and that homosexuals were the scourge of the population.

Just as King's famous *'I have a dream'* speech in 1963 had galvanised the enduring campaign for racial equality in America, so the prohibition of legal segregation the following year had catalysed into action those with prejudicial far-right views. Today, there are countless neo-Nazi groups operating in the United States, with organisations such as the ***'National States' Rights Party'*** *(1958)* and the ***'Nationalist Socialist Movement'*** *(1974)* successfully recruiting more supporters every year. Indeed, since the 1960's there has been a marked increase in the number of active white supremacist groups across America, whilst established ones, including the notorious ***'Ku Klux Klan'*** *(1865)*, have seen a resurgence in activity. Even criminal gangs with far-right affiliations such as the ***'Aryan Brotherhood'*** *(1964)* have gained significant influence in many prisons throughout the country. This upsurge in the activity of white extremists in the latter half of the 20th century naturally lead to the formation of radical counter-organisations such as the ***'Jewish Defense League'*** *(1968)* and the ***'Black Panther Party'*** *(1966-82)* whose reactive strategies could be just as violent.

By the early 2010's, prejudicial right-wing ideology had started to become embedded in mainstream politics, with large conservative fringe movements gaining popularity throughout much of middle America. As the irrational fears of disaffected white voters *(initially from small rural communities)* spread across the country, a growing number of Republican politicians started to legitimise their concerns and, in so doing, made discriminatory attitudes appear more acceptable. This opened up America to a whole new generation of *'alt-right'* politicians, with the voice of prejudice and hate becoming louder within the political establishment. Furthermore, with the election of maverick politician **'Donald Trump'** to president in 2016, elements of racism now began to creep in to official government policy, and far-right political activists became ever more brazen. Whilst the election of Trump was seen by many as just a first step on the way to building a 'white utopia' in America, the influence of racist ideology is already starting to rot the pillars of an open, liberal society there. Indeed there is a growing number of Congressmen with alt-right links, whilst sections of the established media *(including various newspaper publications and television broadcasters)* are also being infiltrated by influential sympathisers. The ultimate desire for most far-right political activists would be to dictate **US** law whilst having full control over its publicity.

Yet it is not just far-right politics that threatens the integrity of American society, with 'religion' also used as a powerful tool for those intent on preaching prejudice and hate. By capitalising on the sense of social injustice felt by many so-called *'white Anglo-Saxon Protestants'*, far-right fanaticism has become entrenched in a growing number of religious communities *(particularly throughout rural America)*. In places where racial hatred and Christianity have merged, young children are routinely sent to church wearing swastikas, where they are instilled with the idea of 'white purity'. Here, in a world where 'god' is seen as supreme perfection and Hitler is revered as the greatest leader of the *'Aryan race'*, Jewish people are portrayed as mongrels, befouled with racial impurities whilst the predominant subject of most Sunday morning sermons is *'Armageddon'*.

Evolving from a loosely organised, far-right social movement in the late 1960's, ***'Christian Identity'*** is the most potent of all racist American theologies. With no centralised doctrine, it unifies a wide range of extremist ideals into a common belief system with strong religious and political attachments. Church meetings within Christian Identity sects consist of exclusively 'white' congregations partaking in services that would typically involve both singing *'Amazing Grace'* and saluting pictures of Hitler.

With its theological roots in late 19th century ***'British Israelism'***, Christian Identity emerged as an offshoot from a North American sect that had established a new militant doctrine of Aryan domination throughout the 1930s. Closely associated with white-supremacist and anti-Semitic organisations such as the ***'Church of Jesus Christ - Christian'*** *(1946)*, ***'Church of Israel'*** *(1972)*, and ***'Aryan Nations'*** *(1974)*, Christian Identity today promotes a racial *(and often violent)* interpretation of Christianity. Advocates believe that only people of Anglo-Saxon, Germanic and Nordic stock can claim to be the true defendants of *'Abraham' (and therefore the ancient Israelites)* whilst people of Jewish origin are seen as the cursed offspring of *'Cain'*. Perceiving ***'The Holy Bible'*** to be their own, most adherents to Christian Identity believe themselves to be direct decedents of *'Adam and Eve'*, and regard Aryans *(rather than Jews)* as the *'chosen'* people. With the *'Book of Revelation'* featuring heavily in their warped beliefs, many see the coming of a holy war/race war from which white Christians will emerge with universal control. Indeed many fanatics will stop at nothing to achieve this aim, and use their abhorrent faith as justification to murder people of other ethnicities.

The dark theological tenets of Christian Identity are gaining influence in thousands of rural communities throughout middle America, and at the heart of its proliferation are a growing number churches that adhere to its beliefs. By gradually infiltrating small Protestant churches over the past few decades, religious extremists have been hugely successful at recruiting new members. In many cases they have become the majority, enabling them to replace incumbent staff and establish new ministries. Indeed, by taking over existing churches, hundreds of movements affiliated with Christian Identity have formed a growing network of like-minded belligerents, allowing them to disseminate religious propaganda and share tactical information on an even greater scale.

By the turn of the present century there were several thousand separate 'Christian Identity' congregations in the **US** with numbers growing every year. Yet the moderate majority of white Christian worshippers in America remain largely silent, with the mainstream churches not raising too much concern. Alas it appears that, whilst there are invariably those who would not take action because they hold similar views, most are either ignorant of the threat, too afraid to challenge it, or both. It is an *'unholy alliance'* that has the potential to destroy the very fabric of American society.

Numerous acts of domestic terrorism have been committed in the United States over the past few decades by people associated with Christian Identity ~ be they terrorist groups such as ***'Army of God'*** *(established in 1982 and responsible for countless deadly attacks on abortion clinics)*, or individuals such as **'Eric Rudolph'** *(perpetrator of the 'Centennial Olympic Park' bombing in Atlanta in 1996)*. A particularly disturbing indictment of Christian Identity is its promotion of *'righteous terrorism'* which became embodied as the ***'Phineas Priesthood'***. It derives from the biblical account of a priest whose brutal murder of a man and his foreign lover ended a plague that *'God'* had wrought on the Israelites for practising sexual immorality. The Idea that Phineas was rewarded with an everlasting priesthood was taken up and popularised by white supremacist **'Richard Kelly Hoskins'** in his 1990 book ***'Vigilantes of Christendom'***. Galvanising further hatred towards America's liberal, multicultural society, Hoskins' book spawned a loose collection of self-styled vigilante groups hell-bent on destroying it. Like other far-right sympathisers, individuals parading as *'Phineas priests'* have targeted everything from abortion clinics and gay bars to churches and schools.

The vicious attacks by various political and religious extremists on everyday institutions that they object to, serves to continuously chip away at the liberal heart of American society. Indeed, despite the protection of individual civil rights being enshrined in the American Constitution, the vociferous intent of many right wing activists is such that they are willing to undermine anything that contradicts their beliefs. Yet, when the actions of the state itself are unnecessarily heavy-handed or prejudice, the most vocal dissent often comes from those with extremist connections *(despite the obvious hypocrisy)* in order to justify their own ideals and strike a chord with passive sympathisers.

A particularly disturbing flash-point in the recruitment of new members to a host of extremist groups occurred in 1993, when the protracted government siege of a ***'Branch Davidian'*** compound near Waco in Texas ended in the massacre of over 80 people ~ most of whom burned to death during the confusion of an '**FBI**' assault. The months that followed saw a sharp rise in people joining anti-governmental groups ~ a number of which proffered extreme ideology and violent proactivity. In fact the second anniversary of the Waco disaster saw a tragic act of perceived retribution that resulted in an even higher death toll. Carried out in 1995 the *'Oklahoma City bombing'* was perpetrated by deluded individuals who used a warped sense of patriotism to justify their actions. Of the many events to have impacted homeland security in the **US** since the Waco siege, only three have been more effective at encouraging recruitment for fanatical alt-right organisations. Two were acts of Islamic terrorism *(namely the 'September 11 attacks' in 2001 and the 'Boston Marathon bombing' in 2013)*, whilst the third was the successful presidential campaign of Donald Trump in 2016.

A steady rise in *'Islamophobia'* throughout the United States over the past few decades has no doubt helped the recruitment drives of numerous extreme right-wing Christian groups there. Moreover, America's growing fear of Islam has had a reactive influence, not just across the country, but throughout the wider world. Whilst, for example, the disproportionate measures taken by the Trump administration to tackle

Islamic fundamentalism within the **US** was widely viewed across the world as being discriminatory, blatant acts of prejudice by Christian extremists deigned to incite further hate and violence have also had a profound effect on the world outside of America. Indeed, even the worst act of Islamic terrorism on American soil, has left a legacy that is far more potent than the attack itself. Besides the many thousands of casualties resulting from 'legitimate' reprisals *(in the form of America's 'war on terror')*, individual acts of defiance, such as those of Florida pastor **'Terry Jones'**, have proved hugely damaging to **US** foreign relations ~ with growing numbers of practising Muslims perceiving America as *'the Great Satan'*. Between 2011-14 Jones burned hundreds of copies of the Qur'an *(the most publicised being on the 13th anniversary of '9/11')* leading to a number of mass demonstrations and deadly riots throughout the Islamic world.

With political and religious extremism rife in the United States, the liberal ideology that has allowed the open democracies of the Western world to flourish is coming under increasing threat. Indeed there is a growing determination among far-right organisations in the **US** to 'rise and conquer', with their ultimate goal being to create a new *'white Christian America'*. With a growing number of American churches succumbing to the beliefs and practices of 'Christian Identity', more and more religious teachings are drawn to apocalyptic prophesies within the Bible ~ with many thousands of adherents believing that the present millennium will hail Armageddon. The most fanatical groups effectively regard the 'Book of Revelation' as a call to arms, with secretive cells across the country stockpiling firearms and attempting to make weapons of mass destruction *(most commonly biological and chemical)* in preparation for their perceived *'holy war'*. Led by blind fanaticism, the tactics of extremists are wide ranging. Not only are they adept at using the Internet to disseminate their propaganda and spread misinformation, but they have successfully infiltrated numerous American institutions, ranging from education hubs and media outlets to strategic government departments and even the armed forces.

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v.

(The fragile peace)

War is a state of mind. There should be no reason to kill other human beings, but with the concept of war it becomes a *'righteous act'*. Indeed in total war it is often an irresistible necessity ~ 'kill or be killed'. The mindset of billions of people is stuck in a human world where the male ego dominates, and the escalation of disagreements *(over both profound and trivial issues)* make it increasingly difficult to back down or concede defeat. As hostilities escalate, our actions are imbued with a growing sense of righteousness, and we feel the need to express our determination to win. We are most likely to be drawn into war when our governments perceive the need for a collective fight to preserve cultural, political or religious principals. In truth however, all deadly conflicts are completely unnecessary and wholly unavoidable.

The futility of war and the brainwashing of modern society to accept it as a legitimate activity *(even if it is seen as an option of last resort)* was most notably emphasised in 2015 by **'Tenzin Gyatso'**, the ***'14th 'Dalai Lama'*** of Tibet. Gyatso highlighted the fact that large military establishments exist <u>solely</u> to kill other human beings yet they are culturally acceptable, and even deemed necessary within today's society. Indeed nearly every country in the world has a sizeable army capable of causing widespread death and destruction. Yet even the most inhumane of dictators could not terrorise and kill their opponents if they didn't have the might of a military organisation behind them. With their existence condoned by society and their use freely sanctioned by government, national armed forces are powerful and often hugely influential institutions.

Because it has been legitimised, war *(as an entity in itself)* is curiously deemed as acceptable, despite being about the most horrific thing that we could possibly witness. During times of peace, the intentional killing of another human is seen as murder ~ an abhorrent crime. Paradoxically however, to fight a war is not regarded as criminal, but as courageous. Indeed to sacrifice one's life in the 'duty' of war *(be it for country or religion)* is regarded as a noble deed, and the fallen are afforded great honour for doing so. Brave it may be to fight a war, but it is certainly not heroic. Attempting to save or preserve life is the only true heroism during war, but it is the protagonists on the battlefield *(particularly when they achieve their deadly objectives)* that are often regarded as heroes.

Whenever a well-intentioned individual willingly enlists for military service, *(whether it be for the **'US Army'**, the **'Iranian Revolutionary Guard'** or the **'Chinese People's Liberation Army')***, most do so in the belief that they are devoting their lives to a just cause ~ where in fact they are simply perpetuating the social conditioning of war. It is clear that, when a nation embarks on a vicious war, the pain and suffering of individual soldiers *(and innocent civilians)* is barely considered in its quest for final victory. In modern warfare, combatants are often equipped with the most advanced weapons systems that are available to them ~ much of which is employed to kill the 'enemy' as efficiently as possible. Yet, far more investment has been made in developing destructive military technology than in protective equipment designed to save human life. The abhorrent tragedy of war is that people are expected to coldly kill complete strangers who, under any other circumstances, they would endeavour to help should danger arise.

No one intentionally goes to war to be killed or maimed themselves. But suffering spreads well beyond the front-line of a war, with pain and heartache invariably felt on all sides by relatives of the fallen. In this way, war spreads hatred and opens up psychological wounds that can take generations to heal. In truth, no one human life is worth more than another *(despite this irrational perception during wartime)*, and the loss of so many human lives is a travesty. Indeed, war should be seen as an anathema to the 'enlightened population' of an open, fair and humane society. But instead war is glorified in popular film and literature, advanced weapons are viewed with awe and fascination, whilst the most successful military figures *(living and historic)* are treated with enormous respect and looked towards for inspiration. Our fascination, as individuals, with murdering one another en-masse for an ideal that may or may not have any relevance to our lives is a unique human condition that is found nowhere else in the animal kingdom. Like many other human qualities it sets us apart, but the ease with which we succumb to such mindless conflict is an obvious flaw in the genetic make-up of our species.

In the centuries that followed the birth of civilisation, all regional human conflicts around the world adhered to established traditions, and little changed for many years. By the onset of *'Industrial Revolution'* in the mid-18th century however, the proliferation of firearms had increasingly begun to standardise the *'art of war'*, leaving honourable traditions to the dead. In Japan, for example, the noble values *('bushido')* of *samurai* warriors, having been practised for over a thousand years, would be virtually extinct within a few more decades, whilst in Europe the time where medieval *knights* adhered to *'chivalrous codes'* of combat had long passed. Although the culture of duelling had persisted into the modern era, the code of chivalry had been subsumed into a new military ethos that put national interests above everything else. Any sense of *'fair play'* was notably absent in the many horrific battles during the ***'Napoleonic Wars'***, for example, which ravaged much of Europe from 1803-15. This was also a time when industry began to change the face of warfare, bringing about the production of armaments on a massive scale *(particularly in Britain and France)*.

The first conflict to mark the age of 'industrial warfare' is generally considered to have been the ***'American Civil War'*** *(1861-5)*. Not only did it see the first battle of steam-powered ironclad warships, but the mass production of interchangeable parts supplied its armies with weapons on an unprecedented scale ~ including the earliest repeating firearms and rapid-fire 'machine' guns. With industrial technologies effectively intensifying warfare, terrifying new horrors were experienced on the battlefield. To this end, in 1863, the 16th **US** president **'Abraham Lincoln'** issued signed instructions to Union Forces concerning their expected behaviour in battle. The *'Lieber Code'* was a comprehensive set of rules that laid out acceptable wartime practices regarding, amongst other things, the governance of martial law, the treatment of prisoners, spies, and deserters and the conditions of armistice.

On a global scale, the Lieber Code provided a solid framework for the ***'Hague Conventions'***; which hosted a series of international treaties and declarations in 1899 and 1907. With a third meeting planned for 1914 but cancelled due to the outbreak of ***'World War I',*** the Hague Conventions codified the boundaries of acceptable conduct during times of conflict ~ laying down the laws and customs of warfare on land and at sea. With the desire of most nations to legally enforce any agreements being vetoed by Germany, the resulting declarations were effectively subject to non-binding, voluntary arbitration. Nevertheless, they lay the foundation for later treaties crucial to the maintenance of both international law and human rights including elements of the ***'United Nations Charter'*** *(1945)* and the ***'Fourth Geneva Convention'*** *(1949).*

Clarifying the actions that constitute war crimes, the Hague Conventions covered many areas ~ prohibiting various inhumane or widely unacceptable wartime practices. These included the pillaging of defeated communities along with the use of collective punishment, the mistreatment of prisoners, and certain perfidious acts of aggression. Besides introducing the first multilateral treaty to prohibit the use of asphyxiating poisonous gasses on the battlefield, the 1899 convention also established a ***'Permanent Court of Arbitration'*** which aimed to provide tribunals for resolving international disputes between member states ~ ranging from issues of sovereignty to human rights.

Alas many aspects of the Hague Conventions were widely contravened in the First World War ~ initially by the Imperial German Army. Heralding the beginning of modern armoured warfare, World War **I** also saw an escalating use of chemical weapons on the battlefield, resulting in many truly horrific outcomes. Indeed poison gas is believed to have killed up to 1.3 million people during the Great War. Whilst the ***'Treaty of Versailles'*** *(1919)* prohibited Germany and the other losing 'Central Powers' from obtaining such weapons again, the desire to reaffirm earlier declarations led to the signing of the ***'Geneva Protocol'*** in 1925. Considered an addition to the Hague Conventions, it was specifically designed to prohibit the use of all chemical and biological weapons in international armed conflict. Indeed within five years virtually all of the main belligerents of World War **I** *(with the notable exception of the US)* had ratified the Geneva Protocol.

Considered to be customary international law in many countries, the Geneva Protocol forbade the use of all biochemical weapons, but not their production, purchase and storage. In fact it was not until 1972 that the ***'Biological and Toxin Weapons Convention' (BTWC)*** finally prohibited the development and stockpiling of biological weapons, whilst the ***'Chemical Weapons Convention'*** designed to augment the destruction of existing chemical munitions was not signed into agreement until 1993. Yet, despite finally being ratified by the United States in 1975 *(after the **BTWC** had presented a 'watered down' agreement that permitted research on the grounds of national defence)* the Geneva Protocol remains, for the most part ineffective. Whilst it may have dissuaded despots such as **'Adolf Hitler'** and **'Joseph Stalin'** from considering the deployment of chemical or biological weapons in open conflict, it did not prevent, for example, the wholesale gassing of Jewish people in Nazi death camps. Indeed, not only has the protocol been breached on countless occasions since its inception almost a century ago, but the **US** *(like China and various other signatories)* have retained reservations that seriously limit its provisions.

Nonetheless, by the start of the 21st century, limited progress *had* been made in reducing the spread of chemical and biological weapons, with the United States making a small but significant contribution. Used by the **US** military for launching nuclear and biological warfare tests during the 1950's and 60's, and for stockpiling of illegal toxic agents in the 1970's and 80's, ***'Johnston Atoll'*** would become America's visible *'declaration of intent'* in its moral obligation to reduce chemical weapons worldwide. Comprising a series of minor islands in the North Pacific, the atoll was 'rebranded' in 1990 as a facility for the storage and disposal of chemical weapons and other hazardous waste, before being completely demilitarised in 2004.

Yet the **US** still possess the ability to manufacture and deploy such weapons at a moments notice, and would not hesitate in their retaliatory use. Meanwhile many smaller, developing nations continue to covertly expand their own biochemical weapons capabilities. Not only do many governments around the world still flout the principles of the Geneva Protocol, but commercial interest is such that the chemical and arms industries of many nations continue to deal within a highly secretive international market ~ with potentially catastrophic consequences. Today, there remains enormous stockpiles of these relatively cheap, and totally indiscriminate 'terror weapons', with autocratic rulers and terrorists alike only too prepared to use them against their perceived enemies should the opportunity arise. Indeed it makes a mockery of international agreements founded on the arbitrary laws of individual nations.

For many countries, it seems that restrictive international agreements simply provide a *'platform of denial'*, while they continue to research, manufacture, trade and stockpile illegal arms. Perhaps the starkest example of this mindset is Russia's clandestine history of dishonouring international regulations in order to satisfy its military ambitions. This was particularly demonstrable during the ***'Cold War'*** *(1947-91)* when justified American distrust of Soviet intentions prompted the **US** 'Department of Defense' to secretly counter what was widely perceived in the West as a one-sided threat from the **USSR**. This resulted in the creation of ***'Project 112'*** *(1962-73)* ~ a widespread biochemical weapons experimentation project involving the **US** government and several 'Western' allies.

Back in 1975, the Soviet Union ratified the **BTWC** but covertly broke the rules *(just as it had done some fifty years earlier with the Geneva Protocol)* ~ and its ongoing research remained largely unchallenged by the West. Even throughout the 1990's, after the Cold War had ended, Russian scientists continued to work on viruses that, in their natural form, posed little or no threat to public health, with a view to developing better biological weapons. Whilst relations between Russia and the West had begun to improve under the country's first post-Soviet president **'Boris Yeltsin'**, new dangers had arisen. With a dramatic reduction in military spending, security around research centres, laboratories and storage facilities in Russia was seriously compromised ~ increasing the possibility that illicit arms technology could find its way into the *'wrong hands'*.

Prior to **'Vladimir Putin'**s presidency in 2000 *(and his subsequent investment in military reform)* Russian forces were somewhat in disarray, and the desire to sell apocalyptic technology for financial gain was palpable. Directed by disaffected *'old guard'* communists, large numbers of neglected military scientists *(including those specialising in bioresearch)* were encouraged to continue their work, with many participants unconcerned at the potential outcome. Indeed, because they can cause massive devastation *(but unlike nuclear arms do not destroy buildings and computer networks)*, these relatively inexpensive and very effective weapons are highly valued on the black market despite their international prohibition. Although smallpox, for example, was officially eradicated in 1999, samples continued to be retained solely for the purposes of biological weapons research and development in both Russia and the **US**. Furthermore, major advances in artificial gene synthesis at turn of century enabled the successful creation of synthetic strains of dangerous viruses, including smallpox and polio.

Today, a vast array of genetic information is available over the Internet with an abundance of websites offering, for example, *'mail order **DNA** testing'*. Indeed, with the advent of modern genetic sciences, **DNA** profiling has become widely used in everything from criminal investigation to environmental protection. However, as new techniques are discovered that allow us to manipulate life at a genetic level, so it becomes increasingly easy for fanatics to develop microbiological weapons designed to target specific ethnic groups. The ability, for example, to insert individual genes at will into existing viruses or bacteria, opens the potential for a whole new arms race, and presents a very dark future for humanity.

The creation of genetically engineered micro-organisms poses the real threat of *'genetic warfare'*, for which all existing international treaties are wholly inadequate. Not only could such weapons be directed to destroy certain ethnic groups or be engineered to delay the release of toxic spores but, were such a conflict to arise, these unique offensive agents would ensure that no vaccine would be immediately available ~ allowing them to wipe out 'enemy populations' with relative ease. Indeed the apocalyptic scenario of 'mad scientists' creating a new *'doomsday virus'* by successfully combining highly resistant strains of smallpox and ebola viruses has become increasingly plausible. Moreover, the genetic sciences have also enabled biological weapons to become increasingly versatile, with advances in *'whole genome sequencing'*, for example, raising the prospect of *'genetic terrorism'*. Military scientists in a number of countries are engaged in projects to create designer pathogens that could be aimed at particular individuals. With such technology, biological agents designed to kill specific world leaders could be released at public engagements without having an effect on anyone else present.

To date, the total number of deaths caused by nuclear, chemical and biological weapons is comparatively small compared to those caused by conventional munitions.

However the dynamics of war are changing rapidly, and in a digital age where scientific advances and technological innovation are constantly pushing the physical and psychological boundaries of human conflict, novel ways of delivering these horrific weapons have been invented. The growing capability of belligerent forces to carry out unmanned drone attacks in 'enemy territory' from the relative safety of a command post thousands of miles away, for example, no doubt increases the possibility that future biochemical atrocities could take place upon targeted populations. Likewise, the ability of a 'hostile nation' to carry out cyber-attacks in order to disable the essential services, or destroy the electronic infrastructure of another country opens the way for further subversive attacks using 'unconventional weapons'. Indeed the growing ease with which chemical and biological agents, *(along with the components of nuclear arms)* are produced, means that such weapons have become more accessible than ever. Although the offensive use of nuclear, chemical and biological weapons is morally objectionable to all but the most fanatical despots, in the event of a 'total' or 'absolute' war their reciprocal use would be deemed no less reprehensible than any other means of destroying or subjugating the 'enemy'.

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vi.

(Weapons of mass destruction: an historical overview)

In 1938, on the eve of the deadliest war of the 20th century, British Prime Minister **'Neville Chamberlain'** uttered the most basic truth about human conflict. He said, *"In war, whichever side may call itself the victor, there are no winners, but all are losers."* Yet mankind, it seems, is painfully slow to learn the lessons of history. Indeed, over the course of the hundred years that followed the end of the ***'Great War'*** in 1918, there have been over 350 separate wars around the world, killing up to 130 million people.

Whilst a vast majority of casualties in major wars invariably die from famine and disease, the wilful intent of combatants is most commonly to *'shoot'*, *'stab'* or *'bomb'* because it is the most direct way to kill an adversary. However in times of 'total war' there is often the temptation of aggressors to use unconventional methods that can *'poison'*, *'infect'* or *'irradiate'* their perceived enemies simply because of the sheer scale of destruction that such weapons can bring. Unlike guns, for example, that are designed to kill their human targets individually, 'weapons of mass destruction' *(or* ***WMDs****)* can be used to indiscriminately obliterate entire communities with a single strike ~ often leaving large numbers of people to die in agony. In a war-torn city that is being bombed using conventional munitions, those under attack *(combatants and civilians alike)* can take their chances by sheltering in buildings and bunkers, but in a city that is being attacked with toxic gas, for example, there is nowhere to hide.

Undoubtedly the most powerful weapons known to man are *'nuclear warheads'* which, when detonated, unleash an almost unimaginable force of energy. The science behind the development of these weapons is fundamentally based on the conversion of matter to energy as denoted by the famous equation '**$E=mc^2$**', which was first revealed to the world by German-born Swiss physicist **'Albert Einstein'** in 1915. The concept of building a weapon that exploited the fissile nature of heavy elements *(such as uranium and plutonium)* in order to set off an uncontrollable chain reaction became the subject of top secret research in Britain, Canada and the United States during the early 1940's. By 1943, the urgent need for collaboration between these wartime allies concentrated efforts into the American ***'Manhattan Project'*** which was co-ordinated by **US** physicist **'J. Robert Oppenheimer**, under the military supervision of Major General **'Leslie Groves'** from the '**US** Army Corps of Engineers'.

Designed at the ***'Los Alamos National Laboratory'*** in New Mexico, the first atomic bomb was detonated in the summer of 1945 at its ***'Trinity'*** test site, 200 miles south in the Jornada del Muerto Desert. Releasing the equivalent amount of energy from detonating 22 kilotons *(22,000 tons)* of **TNT**, the resulting blast wave was detected up to 150 miles away. The Manhattan Project's ultimate contribution to America's war effort in the Pacific was immense ~ culminating, as it did, a few weeks later with the '**US** Army Air Force' dropping atomic bombs over the Japanese cities of Hiroshima and Nagasaki. With the two bombs yielding the explosive forces of around 13 and 21 kilotons of **TNT** respectively, the attacks resulted in a combined death toll of almost 150,000 people, and was effectively the final act of the ***'Second World War'***.

The successful detonation of an atom bomb by the Soviet Union in 1949 lay the foundation for the ensuing ***'Cold War'*** period which would see an arms race of unprecedented idiocy. Russian development was largely centred in the secretive 'research city' of Arzamas 16 *(now the town of Sarov)* in the Nizhegorod Oblast in western Russia. Many scientists working on the project here did so in poor conditions and under enormous duress. Indeed the advance of Soviet nuclear technology relied heavily on forced labour, and the extensive persecution of its 'non-Russian' workforce who were often made to toil in highly dangerous radioactive environments. Despite a high turnover of personnel, the Soviet Union continued to make steady progress, largely because it was well versed at 'acquiring' American technology. As relations between these Cold War advisories naturally deteriorated over the following decades, so mutual distrust grew. Indeed hostilities between the two post-war superpowers intensified in 1950 with the arrest, in Britain, of German particle physicist and key double agent **'Klaus Fuchs'** ~ severely damaging the route for Soviet information.

Seeking to further develop their own nuclear capabilities, American scientists meanwhile were working on a way to fuse hydrogen atoms together. As a result, by 1952, the ***'US Atomic Energy Commission'*** had developed a terrifying new weapon which employed nuclear fission to trigger an even greater destructive force generated by the fusion of hydrogen nuclei. Designed by Hungarian-American physicist **'Edward Teller'** and Polish-American mathematician **'Stanislaw Ulam'**, the first hydrogen bomb *(an 82 ton device code named **'Ivy Mike'**)* was detonated on the Enewetak Atoll ~ a Marshall Islands' territory in the equatorial Pacific. Producing a 10 megaton blast *(equivalent to the exploding force of 10 million tons of **TNT**)* Ivy Mike was almost 800 times more powerful than the ***'Little Boy'*** A-bomb that was dropped on Hiroshima. Within a few years, a number of other world powers *(initially the Soviet Union, and Britain, followed by France and China)* had also developed the 'two-stage' hydrogen bomb, and today many thousands of strategic and tactical thermonuclear warheads are in existence.

Throughout the 1940's and early 50's, the Soviet purge on its Jewish population under **'Joseph Stalin'** had deprived the state of some of its best minds in nuclear science. After his death however, research here improved dramatically, and by 1953 the **USSR** had tested its first hydrogen bomb over the huge ***'Semipalatinsk Test Site'*** in north-eastern Kazakhstan. Yielding a 400 kiloton blast, the Soviet bomb *(unlike the first American one)* was small enough to be dropped from a plane, and a terrifying new arms race ensued. Over the next few decades phenomenal power was unleashed in numerous tests, with both sides developing H-bomb refinements at an alarming rate. With several other countries developing their own nuclear capabilities, by the turn of the century, the potential for *'mutually assured destruction'* had grown considerably.

Although there are fewer nuclear warheads in full commission today than there were throughout most of the Cold War, the potential for global annihilation has not diminished. Indeed a number of nation states *(including Israel, Pakistan, and North*

Korea) currently possess the ability to exact a nuclear strike upon their chosen enemies, despite the precarious nature of their own social stability. By far the greatest number of thermonuclear weapons, however, remain in the possession of the United States and Russia who have a long history of nuclear rivalry. America's nuclear arsenal peaked in the mid-1960's at just under 32,000 warheads, whilst the Soviet Union had stockpiled just over 40,000 by the mid-1980's. During the second half of the 20th century, these two nuclear superpowers had carried out almost 1800 tests between them ~ condemning vast areas of our planet to dangerous levels of background radiation.

Within a couple of years of detonating their first hydrogen bomb the **US** had, by 1954, perfected a fully deployable, high-yield thermonuclear weapon design. Their ***'Castle Bravo'*** test over Bikini Atoll *(200 miles east of Enewetak)* produced an unpredicted 15 megaton explosion that caused widespread contamination, exposing island residents living up to 300 miles away to dangerous levels of radioactive fallout. The most powerful bomb however was a three-stage, *'fast fission'* device developed by the Soviet Union in the 1960's, which was capable of yielding explosions in excess of 100 megatons. Despite the being scaled down to reduce nuclear fallout, the 57 megaton ***'Tsar Bomba'***, *(tested over Severny Island in the Russian Arctic in 1961)* produced ten times the amount of energy than all of the conventional explosives used in World War **II** combined, and remains the largest manmade explosion to date.

Although the detonation of Tsar Bomba represented the pinnacle of nuclear belligerence during the Cold War arms race, because of its efficient design *(97% of the explosion resulted from fusion energy)*, radioactive contamination of the wider region was comparatively low. This was not the case, however, with a vast majority of active nuclear warheads deployed during the Cold War. Indeed, in the 1960's, it was calculated that for every megaton of explosive yield produced by a thermonuclear warhead, around 10,000 people would be killed by the radioactive fallout alone. As for the explosion itself, a typical 15 megaton bomb would cause the complete obliteration of life within a thirty mile radius.

The frightening arms race between *'East'* and *'West'* escalated and intensified right up until the early 1990's. Yet, even though the Cold War ended several decades ago, a considerable number of modern nuclear 'deterrents' still remain in service. Indeed, today there are approximately 16,000 fully operational nuclear warheads ~ the largest of which are well over a thousand times more powerful than both the Hiroshima and Nagasaki bombs. Despite a raft of international treaties and agreements designed to reduce their numbers and prevent further proliferation *(including the **'Non-Proliferation Treaty'** ['**NPT**' - from 1968] and the **'Strategic Arms Reduction Treaties** ['**START**' active between 1982-2009])* there are still enough nuclear warheads in the world to detonate the equivalent of around 600,000 Hiroshima bombs ~ with the collective potential to bring about the complete annihilation of human civilisation many times over.

Most components that make up a nuclear warhead are very expensive and highly complex but the availability of, and access to, material parts *(along with the necessary construction skills)* are becoming increasingly widespread. This has allowed a growing number of aggressive nation states the ability to pursue offensive nuclear technology, should they so desire. When you consider the fact that only 8kg *(17lbs)* of plutonium is enough to destroy a city the size of Paris yet, to date, over 1400 tons of it has been produced as a by-product of atomic reactors, the potential for a *'nuclear holocaust'* becomes clear. Indeed since the start of the atomic age in the mid-1940's there have been numerous historic incidents that have compromised the security of human civilisation. Infamous accidents include the mid-flight break-up of a ***'United States Air Force'*** B-52 bomber carrying two thermonuclear warheads in 1961. As a result, the bombs *(each capable of yielding a 4 megaton explosion)* were dropped over the village of Faro, near Goldsboro, North Carolina, with one almost completing its arming sequence. Another major accident occurred in 1986 aboard the ***'Soviet Navy'*** submarine K-219, when an explosion in one of its missile tubes resulted in the loss of the vessel along with its 34 nuclear warheads in the North Atlantic Ocean. Incredibly, over the course of the Cold War, a total of seven fully-armed Soviet nuclear-powered submarines were accidentally sunk.

Of course it is not just military 'accidents' that carry the risk of unforeseen nuclear disasters. Intentional nuclear brinkmanship has the potential to unleash even greater devastation upon the world. Perhaps the most infamous Cold War confrontation between East and West was the *'Cuban missile crisis'* in 1962, when the proposed deployment of Soviet ballistic missiles in Cuba, resulted in a military blockade by America ~ raising tensions between the two nuclear superpowers considerably. A Soviet response to the failed ***'Bay of Pigs Invasion'*** *(an aborted **US**-funded coup)* the previous year, as well as the presence of nuclear missiles on American air bases in Italy and Turkey, this incident came close to escalating into a full-scale nuclear war. Whilst tensions over the Cuban crisis were eventually diffused, a number of other dangerous confrontations occurred over the following decades.

Alas reckless military belligerence did not end with the Cold War. The ongoing testing of nuclear warheads and ballistic missiles by North Korea, for example, in violation of the 1996 ***'Comprehensive Nuclear Test Ban Treaty'*** *(from which it withdrew in 2003)* has garnered considerable international condemnation. Following its first successful detonation of an atomic bomb in 2006, in a little over ten years North Korea had managed to develop weaponry that could strike mainland **USA**. Its continued endeavour to create a fully functional intercontinental ballistic missile system capable of carrying a nuclear payload is a highly dangerous pursuit that risks escalating into a full military confrontation with the United States. This would no doubt have significant consequences for the future of modern civilisation.

Mankind faces the threat of numerous self-inflicted disasters that have the potential to bring about the collapse of modern civilisation ~ many of which involve weapons of mass destruction. Whilst the damage done by the accidental detonation of a nuclear warhead or the unintentional release of an armed ballistic missile could bring about dangerous global instability, the likelihood of nuclear weapons being used with intent *(for example as an act of terrorism or as the result of intractable belligerence between nuclear rivals)* only increases over time. Indeed there have been many 'flashpoints' in recent history that have changed the dynamics of the nuclear 'status quo'. The break up of the Soviet Union in 1991, for example, instantly created four separate nuclear states. Although Belarus, Ukraine and Kazakhstan ceded their weapons to Russia in the mid-90's, nuclear security was severely compromised during this time with Soviet technology and materials turning up in countries such as Syria, Libya, Iran and North Korea. Meanwhile Chinese technology was also instrumental in the rapid advance of Pakistan's nuclear capabilities throughout the 1990's. As a result, a regional arms race between Pakistan and its historic adversary India intensified and, with neither country party to the 'non-proliferation Treaty', it has become another potential hostspot for nuclear disaster.

Whilst a number of nations *(including Germany, Italy and Turkey)* provide bases for the storage and deployment of American weapons under **NATO** command, the further proliferation of nuclear arms across the wider world could readily undermine global security and is therefore greatly discouraged by the international community. The intense scrutiny of nuclear research in less wealthy, developing countries *(particularly when they are perceived as a potential threat to the West)* is reinforced by the possibility of economic sanctions or even military action if international law is deemed to have been grossly violated. Generally *(as with North Korea's illicit nuclear programme)* punitive measures by the international community take the form of sanctions agreed by the United Nations ~ however this is not always the case. The invasion of Iraq in 2003 by Western coalition forces, for example, was undertaken without a **UN** mandate. Self-justified in the mistaken belief that the country had an advanced nuclear and biological weapons programme, the resulting conflict had lasting and hugely damaging consequences for both the Middle East and the wider world.

An 'unsanctioned' operation to cripple Syria's clandestine nuclear programme in 2007 however proved far more successful. Indeed the bombing of Syria's secret facility in the 'Deir ez-Zor' region, by Israeli forces, effectively ended the country's nuclear ambitions. Yet not all 'unauthorised' nuclear research is forcibly shut down by foreign intervention. Having built a number of deliverable atomic bombs in the 1980's, by the end of the decade South Africa, for example, had voluntarily dismantled its weaponry in order to consolidate regional stability. In 2003 Iran also suspended its nuclear weapons programme, this time as a result of sustained international pressure. However the growing accessibility of nuclear weapons technology, and the military ambitions of the countless despots to come poses a continual threat to peace and stability around the world.

The true horror of a nuclear explosion is revealed to those who, perchance, may be far enough away to survive an initial blast, but close enough to fall victim to the radioactive fallout that inevitably follows. When detonated over flat terrain, a 10 megaton hydrogen bomb, for example, will cause spontaneous combustion to occur within a twelve mile radius of 'ground zero'. However, even in calm meteorological conditions, during the next 48 hours such an explosion would distribute dangerous radioactive material over a vast area ~ with nuclear fallout *(consisting of contaminated dust and by-standing atoms)* likely to rain down up to two hundred miles away.

Whilst exposure to high levels of fallout will cause acute radiation poisoning, killing victims within a matter of days or weeks, those who may survive the immediate aftermath of a nuclear attack are also at greater risk of falling victim to any number of radiation-induced cancers in later years *(including leukaemia, thyroid cancer and malignant melanoma)*. Moreover the *'double-edged sword'* of a nuclear attack can have serious consequences on the lives of people who did not even witness the event at first hand. Indeed the potency of ionising radiation is such that it can even adversely effect the long-term health of later generations ~ with genetic deformities causing birth defects and considerably raising the susceptibility of children to numerous ailments and diseases.

Despite the agonising death caused by radiation poisoning, the first 'enhanced radiation weapons' *(more commonly known as the 'neutron bomb')* entered production for the **US** military in 1974. First described two decades earlier by **US** physicist **'Samuel T. Cohen'** and his team at the ***'Lawrence Livermore National Laboratory'*** in California, the neutron bomb was a horrific development in tactical nuclear technology. It was built specifically to administer large doses of radiation to the inhabitants of a targeted city or instillation, but designed to produce minimal blast so that more buildings in the vicinity of an explosion would remain intact. Indeed, with its high energy neutron pulse outpacing the physical explosion itself, the detonation of a 1 kiloton neutron bomb would deliver almost ten times the amount of lethal radiation than the 'Hiroshima bomb', despite having a far smaller yield.

Without nuclear weapons, the face of modern warfare would be completely different *(no doubt chemical and biological weaponry would play a more prominent role in 'superpower diplomacy' than it presently does)*. Indeed, the largest 'conventional' explosive weapons, though sinister, are minuscule by comparison. ***'Thermobaric weapons'*** that utilise airborne oxygen to greatly intensify an explosion can cause enormous devastation to a targeted area. Most casualties of a 'thermobaric attack' fall victim to the immense pressure wave that immediately precedes a sustained fireball ~ as the auto-ignition point of its vaporous fuel is prolonged by oxygen drawn from the surrounding air. Yet even the largest of these so-called *'vacuum bombs' (namely the Russian 'Father of All Bombs' ~ or **'FOAB'**)* is only capable of yielding a blast equivalent to exploding 44 tons of **TNT** ~ a fraction of the energy dispersed by even the most modest tactical nuclear weapon.

Meantime, the comparative inefficiency of ***'radiological dispersal devices'*** *(or **RDDs**)* that use conventional explosions to diffuse radioactive material across a targeted area, make them virtually obsolete to all but the most committed terrorist organisations. Known commonly as *'dirty bombs'*, the amount of radioactive contamination that **RDD**s can cause is minimal when compared to actual fissile explosives, and their use is more effective as psychological deterrents than as practical weapons of mass destruction. Indeed, in terms of its pure obliterative power, no other manmade weapon comes close to the nuclear bomb.

Fission and fusion bombs are by no means the only contaminant weapons of war. Also classified as **WMD**s, many modern chemical and biological weapons are capable of producing equally horrific injuries, and *(like the radioactive by-products of nuclear explosions)* some have the potential to render 'affected land' inhabitable for many years. Although they have not been deployed on the same scale as conventional weapons, unlike nuclear weapons, both chemical and biological agents have, nonetheless, been widely used in anger.

Chemical weapons, in the form of poison-tipped arrows and spears, were regularly used throughout human prehistory. Likewise the burning of toxic chemicals, such as arsenic or sulphur, to produce noxious smoke as an effective weapon *(particularly in siege warfare)* has been known for millennia. It was the industrial age however that brought new methods of delivery, as well as a frightening array of new weapons. By the late 19th century artillery shells containing cyanide, arsenic and liquid chlorine had been designed but the perceived illegitimacy of chemical weapons largely prevented their use.

The use of chemical weapons in modern warfare really began in 'World War **I**'. Indeed a variety of poison chemicals were investigated and 'weaponised' during the Great War, with the *(largely)* non-lethal tear gas ***'ethyl bromoacetate'*** being the first chemical adapted for offensive use by France in 1914. Although, proving unsuccessful, Germany's use of the painful irritant ***'xylyl bromide'*** against the Russian Army in 1915 was the first large-scale attack using shells containing harmful chemical agents. Whilst a number of other noxious but 'comparatively mild' incapacitants such as ***'chloracetone'***, ***'bromoacetone'*** and ***'camite'*** were introduced to the battlefield over the next few months, the development of increasingly toxic chemical weapons would severely deepen the depravity of this war.

Contrary to the ***'Haig Conventions'*** of 1899 and 1907, deadly chemical weapons were widely developed and used by all sides during 'World War **I**'. The first such weapons to be deployed on a mass scale took the form of canisters containing highly toxic choking gasses *(initially* ***'chlorine'*** *and, later,* ***'phosgene'****)* which were propelled towards enemy lines ~ a tactic used to devastating effect on the Western Front. With deadlock on the battlefields of Belgium and France, it was the German Empire that took the initiative to attack Allied positions with gas, and break the military impasse. Seen as an inexpensive way to kill great numbers of enemy troops, German research was led by celebrated Prussian chemist **'Fritz Haber'** whose involvement significantly effected the course of the war. A particularly gruesome development in modern trench warfare, the addition of chemical attacks and the continued evolution of new weapons required an unprecedented level of co-operation between scientists and the military. Yet, despite the advanced state of German military research, stockpiles of chemical munitions were not immediately used, with the old 'habit' of chivalrous conduct initially delaying their deployment by the 'Imperial German Army'.

On the 22nd April 1915 however French colonial forces *(largely comprising Moroccan and Algerian troops)* positioned at Ypres in north-western Belgium became the first victims of a deadly gas attack ~ perpetrated by the German Army. Over the following days thousands of Canadian, Belgian, and British soldiers would also succumb to German chemical attacks. The introduction of chlorine canisters as a terrifying new weapon at the ***'Second Battle of Ypres'*** only added to the depraved horrors of modern war ~ with choking yellow-green clouds now drifting across Allied trenches, poisoning everything in its path.

Chlorine gas was used by the Germans on at least four separate occasions during the month long battle, and was responsible for the deaths of up to 6,000 troops ~ severely injuring almost double that number. Wiping out huge swathes of both vegetation and animal life, the introduction of chlorine gas to the battlefield in Ypres was uniquely sinister in breaking the last taboo of war. Besides causing painful asphyxiation, it turned skin a greenish black and yellow on contact, with the aftermath of these attacks revealing a surreal countryside strewn with stained corpses and their weapons. Alas a new arms race was started on that fateful day in April 1915 ~ heralding the progressive evolution of modern **WMD**s.

The use of chlorine gas at Ypres was considered by Allied Forces to be an underhand atrocity but, once it had been deployed by the German Empire, public pressure for the retaliatory use of poison gas was immense. As such, the next chemical weapon to be developed and widely used during the war was the insidious poison phosgene, which had originally been synthesised by English chemist **'John Davy'** back in 1812. A colourless gas with a subtle 'straw-like' odour, phosgene was initially weaponised by French chemist **'Victor Grignard'** shortly after the Second Battle of Ypres and, within a couple of months, both France and Germany had manufactured thousands of tons of it. Approximately 18 times more potent but slower acting than chlorine gas, phosgene was responsible for more deaths during the war than any other offensive chemical agent. Most standard issue gas masks designed to protect against chlorine attacks were no defence against phosgene which, when inhaled, disrupted the blood-air membrane of the lungs, causing victims to effectively drown in their own body fluids.

Such was the scale of destruction a well-planned chemical attack could wreak that, by the end of 1915, Germany had even developed a particularly lethal chlorine-phosgene combination 'gas shell' which it promptly put to use, with moderate success against British soldiers on the Western Front. Meantime, the outrage felt in Britain at the use of deadly gas attacks against its troops in Belgium led to the further development of both offensive chemical research and anti-gas defences. The ***'Porton Down 'Chemical Defence Establishment'*** *(later the* ***'Chemical and Biological Defence Establishment')***, in Wiltshire, Southern England was set up to research and exploit this new area of warfare. Here too, they initially developed gas shells containing chlorine and phosgene, but soon turned to researching new types of chemical *(and later biological)* weapons. Not only was the successful deployment of chlorine and phosgene heavily dependant on prevailing weather conditions, but protective countermeasures against these tried and tested choking agents were quickly improving.

Intensive research in Britain, Germany, and the **USA** during the war led to the introduction of the first weaponised incendiary chemicals including ***'white***

phosphorus' smoke shells *(in 1916)*, and ***'benzol'***-filled bombs *(in 1918).* Another line of offensive chemical research involved volatile blister agents such as ***'sulphur mustard'*** *(in 1917)* and ***'lewisite'*** *(in 1918).* Whilst lewisite was developed too late to be effectively used in World War **I**, sulphur mustard *(better known as 'mustard gas')* was not. A persistent, and truly harmful vesicant, mustard gas wrought indiscriminate destruction ~ killing over 14,000 people in the first three weeks of its use. When enveloped in a cloud of mustard gas, victims would experience a burning blindness along with an excruciating struggle for breath as it attacked their bodies, causing severe damage to their eyes, lungs and throat. Highly carcinogenic and readily absorbed through clothing, mustard gas does not evaporate but, on contact, sticks to the skin and gradually burns it away. Indeed, it was not just enemy troops who fell victim to mustard gas during 'World War **I**', but thousands of civilians, along with cattle, pets and local wildlife *(most noticeably birds and rodents)* all died in its path.

The use of chemical weapons during the 'Great War' ultimately inflicted hundreds of thousands of casualties on both sides. However the number of fatalities was comparatively low *(when compared to those caused by conventional munitions)* largely thanks to the swift development of protective measures against the first choking gasses, and their limited deployment. Thankfully the war drew to a close before intensive research into new and more effective chemical weapons could really bare fruit.

The continuing threat to humanity posed by chemical weapons, however, needed to be addressed. This was done by the 1925 ***'Geneva Protocol'*** which strictly forbade their use in armed conflict. Yet, throughout the inter-war years, many countries continued to develop new chemical weapons ~ with some *(including Italy, Japan and Germany)* deploying them against their enemies in clear violation of the treaty. In addition, Germany's flagrant disregard for the 1919 ***'Treaty of Versailles'*** enabled the continuance of its research into organophosphorus nerve agents that were far more deadly than anything previously developed. Taking gas, liquid or aerosol form, this new range of highly toxic chemicals was developed by German chemist **'Gerhard Schrader'** and his team at ***'IG Farben'*** in Leverkusen. Adapted for weaponisation at the ***'Spandau Citadel'*** in Berlin and manufactured at secret locations around the country, thousands of shells containing extremely dangerous agents such as ***'tabun'*** *(from 1936)* ***'sarin'*** *(1938)* and *later* ***'soman'*** *(in 1944)* were stockpiled by Nazi Germany but thankfully did not see action in 'World War **II**'.

In the last three years of the war itself however, other chemical weapons were used to horrific effect. ***'Zyklon B'***, a composite poison gas based on the powerful blood agent hydrogen cyanide, had originally been developed in 1922 at ***'Degussa AC'*** in Essen, by a team of scientists including German chemist **'Bruno Tesch'**. Pre-war research into Zyklon **B** *(like that of tabun and sarin)* was disguised as pest control, but some twenty years later it would be widely used to commit the mass murder of over a million Jews in Nazi death camps. Indeed, whilst Tesch's complicity in the gassing of prisoners would lead to his own execution after the war, this genocidal atrocity remains the most deadly use of any chemical agent in human history.

Although the Nazis refrained from employing chemical weapons on front line attacks against major Allied forces during the war, they did use a range of deadly poisons *(including mustard gas and Zyklon **B**)* on their so-called 'ethnic enemies' ~ defying the Geneva Protocol and Treaty of Versailles on countless occasions. Immediately after the war, a number of secretive laboratories and chemical production plants, along with thousands of unused chemical shells were discovered by the Allies. Indeed the Nazis had enough tabun to wipe out the entire city of London, but preferred to use conventional incendiary bombing ~ primarily because it also destroyed infrastructure. However, with tabun being several hundred times more potent than chlorine gas, such an attack on London would likely have killed up to a million civilians and severely crippled the Allied war effort. Yet even more deadly chemical agents were being developed by both sides, and Hitler was well aware that Germany would likely face unknown reprisals against its own cities.

One such Allied line of research centred on the production of new types of incendiary bombs filled with highly flammable chemicals ~ the most infamous of which was ***'napalm'***. Originally developed in 1943 by **US** chemist **'Louis Fieser'** at ***'Harvard University'*** in Cambridge, **MA**, napalm constitutes a form of jellied petroleum that undergoes a slow but intense combustion when ignited. Employing the palmitic fatty acids of coconut oil as a part of the gelling agent, it is capable of generating temperatures in excess of 1000°**C**, and was considered by the Allies to be a viable alternative to conventional 'thermite' incendiaries. Napalm is a particularly ferocious incendiary chemical however, and air attacks using napalm leave a unique signature of death. Not only does it readily stick to skin and clothing but it destroys the breathable atmosphere, saturating the surrounding air with very high levels of carbon monoxide ~ killing those in the close vicinity who might otherwise survive. Indeed in the immediate aftermath of a napalm attack, anyone caught in the hot suffocating air would likely succumb to hyperthermia or severe hypoxia.

In the final years of the Second World War, napalm-filled bombs appeared in a growing number of Allied air attacks on both German and Japanese positions, but it was in the protracted Vietnam War during the 1960's and 70's that it really gained notoriety as a tactical chemical weapon. Here it was used with devastating effect by the **US** Air Force ~ with attacks creating huge firestorms that destroyed vast swathes of both farmland and forest. The horrific injuries sustained by survivors of napalm attacks also made it an effective psychological weapon against the Viet Cong. Indeed almost twenty times the amount of napalm was dropped on Vietnam by American and South Vietnam forces than was used during the entire Second World War.

Throughout the 1940's and 50's a large number of terrifying new weapons were developed by the Americans and Soviets, along their 'Cold War' allies. Both 'East' and 'West' used German technology to research nerve agents, and enough was produced to kill everyone in the world several times over. Only the fear of retaliation in kind prevented their widespread use in combat.

Perhaps the most effective of all 'non-nuclear' weapons of mass destruction is ***'VX gas'*** ~ one in a series of persistent nerve agents developed at Porton Down during the mid-1950's. The first of the so-called *'V-series'* nerve agents, ***'VG'***, was initially synthesised in 1952 by British chemist **'Ranajit Ghosh'** who was researching new organophosphorus pesticide at *'ICI'*s Jealott's Hill laboratory in Berkshire. Indeed **VG** was briefly marketed as the powerful insecticide ***'Amiton'***, but would be deemed too hazardous for agricultural use and was soon withdrawn. However, the potential for militarising this compound into a new family of chemical weapons was quickly recognised, and further research at Porton Down led to a number of chemically similar nerve agents being developed.

Produced in liquid or aerosolised form, **VX** *(venomous agent X)* was first created two years after **VG** and is one of the most potent of all synthetic poisons. It is a strong, highly toxic, adhesive chemical that attacks the entire nervous system ~ bringing about an agonising death to anyone who encounters it unprotected. Like the other **V-**series nerve agents, the low volatility of **VX** means that it does not readily disperse, and can seriously pollute the environment for many months or even years. Not only does **VX** prove deadly when inhaled, but it is readily absorbed through the skin and eyes, from which a dose of as little as 10mg *(3½ oz)* can kill in under two minutes. Only the most potent variants of the ***'novichok'*** series of nerve agent, *(developed in the 1970s and 80's by the Soviet Union)* are of comparable or higher toxicity.

Not all weaponised poisons however are intentionally produced to be as deadly as **VX**. Indeed military research into more 'sophisticated' chemical incapacitants was just as intense during the post-war 20th century. Primarily designed as a non-lethal nerve agent, ***'BZ gas'***, for example, is a slow acting, belladonna-based poison which has been stockpiled by a number of countries for possible deployment in the event of civil war. Chemically known as *'3-Quinuclidinyl benzilate'*, **BZ** was originally developed by the Swiss pharmaceutical company ***'Hoffman-LaRoche'*** in 1951 as an anticholinergic drug designed to treat various gastrointestinal conditions. However, by 1959, its psychotropic properties had been further investigated by the **US** military at ***'Edgewood Arsenal'*** in Maryland. Here **BZ**, *(along with numerous other chemical agents and psychoactive drugs)* was thoroughly tested on human subjects to establish the practicalities of any potential military application. Within two years, it would be weaponised and stored in huge quantities ~ initially at ***'Pine Bluff Arsenal'*** in Arkansas.

Completely odourless, **BZ** is a strong hallucinogen that debilitates the peripheral nervous system. Often stuporforic in nature, the delayed symptoms of **BZ** can seriously incapacitate victims for several days. As a result, under international law *(namely the 1993* ***'Chemical Weapons Convention'*** *[CWC])* it is considered to be a controlled substance whose use is highly restricted. Yet it is one of many toxic chemicals that has countless variants just waiting to be independently researched by one oppressive government or another. At the same time that **BZ** was being investigated in the United States, similar research in the Soviet Union centred on a series of powerful opuim-based narcotic gasses derived from *'fentanyl'* ~ many of which were produced at a secret military research facility in Leningrad. Designed primarily as powerful incapacitants, these dangerous narcotics can also prove to be deadly. For example, the heavy-handed use, by Russian special forces, of ***'kolokol-1'*** *(which contains the highly potent synthetic opioid 'carfentanil')* inadvertently killed over 130 people during the 'Moscow theatre hostage crisis' in 2002.

Another type of chemical weapon was borne from the concept of *'herbicidal warfare'*. Initially researched in Britain and the **US** during the Second World War, the idea of using powerful herbicides to attack crops and deprive Axis forces of vital food supplies was not deemed practicable at the time. However, during the 1950's and 60's, numerous countries around the world invested in the research and development of powerful herbicides and defoliants for military use. Initially developed by the **US** Army in 1961, perhaps the most notorious were the *'rainbow herbicides'* which would see widespread deployment in Vietnam from the following year.

So named after the regulatory coloured stripes painted onto the containers *(as a way to identify each specific agent)*, the rainbow herbicides were a range of herbicidal weapons designed to gain tactical advantage for **US** forces in the Vietnam War. The primary aim of using these weapons was to deprive the Viet Cong of both forest cover and vital food sources, but, besides causing extensive environmental damage throughout Vietnam, they ultimately led to widespread famine in numerous rural communities ~ and the starvation of thousands of villagers.

Over the course of the Vietnam War, **US** forces dispersed tens of thousands of tons of different herbicides and defoliants, much of which was contaminated with highly toxic residues. The arsenical herbicide ***'agent blue'***, for example, was largely used to destroy paddy fields ~ drying out rice crops and leaving the land unsuitable for further cultivation. The most heavily used herbicidal weapon during the war however was the infamous ***'agent orange,'*** which caused incalculable harm to the country's natural ecosystems. Chemically identical to a compound that had been successfully used by British forces during the 1950's *(for a starvation campaign against communist forces in Malaya)*, agent orange is essentially an equal mixture of two different phenoxyacetic acids. One of these *'**2,4,5-T**' (also known as 'trioxone')* is readily tainted during the manufacturing process, which can also create small amounts of *'**2,3,7,8**-tetrachlorodibenzodioxin' (or '**TCDD**')* as a by-product ~ the most potent of all known dioxins. The unregulated preparation of trioxone ultimately contaminated most of the agent orange *(as well as similar herbicides such as **'agent green'** and **'agent pink'**)* used by American forces during the war.

Although agent orange itself breaks down relatively quickly in the environment *(particularly when it is exposed to sunlight)*, the **TCDD** within it does not. A persistent organic pollutant and known carcinogen, **TCDD** residues left behind from herbicidal attacks by American forces during the 1960's and 70's continued to poison fertile soils of Vietnam for several decades after. Yet even in the knowledge of its long-term spoliation of the land, and its devastating effects on local populations, the **US** military continued with widespread deployment of agent orange as a tactical weapon against the Viet Cong. Indeed, within a couple of years they had discovered that by combining it with the synthetic herbicide *'picloram' (an active constituent of the chemically unrelated **'agent white'**)*, they could create an even more powerful herbicidal variant ~ ***'super orange'***.

In excess of 20 million gallons *(91 million litres)* of herbicide was sprayed over Vietnam by American forces during the war, with agent orange alone destroying almost 6 million acres *(24,200km²)* of forest and arable land in a little under nine years. The severity of herbicidal attacks by the **US** military on the natural vegetation of Vietnam *(particularly at the Laos and Cambodian borders)* had damaging long-term effects on the forest ecosystems and a significant impact on biodiversity in the region. Indeed, little or no consideration was given to anything other than flushing out and killing enemy fighters, with spray runs of agent orange often followed up with blanket napalm attacks. After the war, native plants in many affected forest areas were slow to re-establish, and were often disadvantaged by the presence of hardy, fast growing invasive species. This, in turn militated against the successful repopulation of indigenous wildlife.

The consequences of America's immoderate use of offensive herbicides during the Vietnam War, however, runs much deeper than to just the irreparable environmental damage that it caused. With elevated levels of dioxin and arsenic remaining in the water table to this day, millions of people continue to live with serious health issues as a direct result of **US** participation in the war. Besides poisoning the food chain, **TCDD** exposure amongst the Vietnamese population has led to a wide variety of medical problems ~ ranging from skin, nerve and respiratory diseases, to immune system disorders, genetic diseases and numerous cancers. Moreover many thousands of American personnel were also exposed to agent orange *(and a number of other hazardous chemicals)* that were stockpiled at military bases throughout South East Asia. As a result, the genotoxic properties of **TCDD** has also led to a raised number of stillbirths and congenital disorders *(including dysmelia, and spina bifida)* amongst children fathered by affected servicemen.

The Vietnam War saw the use of more chemical weaponry than any other conflict to date. Indeed, the **US** military used vast quantities of napalm and various herbicides in their desperate attempt to defeat the tide of communism in Vietnam. Furthermore, from 1967 thousands of tons of painful irritants and incapacitants *(including 'phenacyl chloride', '**CR gas**', and '**CS gas**')* were also directed against the Viet Cong. Yet, although potentially lethal *(and later prohibited by the **CWC** for offensive deployment during war)*, these and various other lachrymatory agents are now widely used for riot control by numerous civilian administrations.

Despite being internationally outlawed, since the Vietnam War a number of far more deadly chemical agents have also been used in various conflicts around the world against 'enemies' that couldn't respond in kind. In the mid-1980's, for example, the intervention of Cuba in the 'Angolan Civil War' resulted in chemical attacks against suspected insurgents *(using mainly sarin and VX)* without any regard for the civilian population. The most lethal chemical attacks in modern history, however, were perpetrated by Iraqi forces under **'Saddam Hussein'** during the 'Iran-Iraq War'. Between 1980-88 well over 60,000 people *(including thousands of Iranian and Kurdish civilians)* were killed by numerous Iraqi chemical attacks. Beginning with the sporadic use of mustard gas in bombing raids on Iranian positions, the Iraqi military went on to employ a range of organophosphate nerve gases against its enemies ~

including tabun, sarin, and ***'cyclosarin'*** *(the deadliest of all Nazi-era chemical agents).*

Ideal as a weapon of terror, the use of lethal chemical agents has been exploited on a number of occasions in the Middle East. Towards the end of the Iran-Iraq War, for example, Iraqi forces used chemical bombs on several border towns and cities ~ including the Kurdish city of Halabja in north-eastern Iraq which, in 1988, suffered the largest single chemical attack to have ever been directed against a civilian population. Killing more than 5,000 men, women and children outright, Iraqi jets bombed access roads out of the city with sarin before directly attacking residential areas with mustard gas and hydrogen cyanide. With its population still experiencing a higher number of related cancers, birth defects and miscarriages, the people of Halabja will continue to suffer from this single deadly attack for many decades.

A variety of lethal chemical weapons was also used some 25 years later, during the 'Syrian Civil War', resulting in the deaths of several thousand more civilians. Under the dictatorship of **'Bashar al-Assad'**, the Syrian military was responsible for several sarin and chlorine gas attacks on rebel-held districts in a number of cities *(including Damascus, Aleppo, and Homs)*. Prior to the civil war Syria's stockpile of chemical weapons was believed to have been one of the largest outside of Russia and the United States. Ravaged by a protracted and hugely destructive war however, the diminishing security of Syria's weapons facilitated their growing use as the conflict intensified. Indeed a particularly vicious belligerent of the wider war *(the self-proclaimed **'Islamic State'**)* even began to manufacture its own mustard gas for use against dissenters of its strict regime. Alas so long as there are despots and fanatics prepared to exploit the indiscriminate nature of **WMD**s as a way to enforce their own warped agendas, then chemical and biological weapons will remain a constant threat to humanity.

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Although they are less adaptable than chemical weapons, biological agents also have a long history of being weaponised ~ with infectious diseases such as ***'tularaemia'***, ***'plague'*** and ***'smallpox'*** all used to deadly effect in various battles and sieges throughout the ages. By the early 20th century, advances in both microbiology and military technology had led to a concerted effort in many countries to culture deadly bacteria, fungi and viruses in order to adapt them for use against prospective enemies. As a result, a wide range of different microorganisms were tested for their destructive abilities, and many were eventually weaponised. However, modern germ warfare has the potential to wipe out humanity in a matter of months, and a 'total war' involving the widespread use of biological weapons is not considered to be a viable prospect for any military force *(that is not beset by extremist ideology).*

Whilst there have been numerous 'limited' attacks using biological weapons throughout modern history, thankfully a full-scale biological war has yet to manifest. Although the threat of 'bioterrorism' continues to grow, biological weapons are unlikely to ever be used as a 'first strike option' by any modern military force engaged in an international war. Indeed they are far more likely to be deployed in the aftermath of a nuclear attack as a means of 'eradicating' remaining survivors.

Huge stockpiles of biological weapons certainly exist today *(as does the capability to readily manufacture and deploy them)*, but their apparent underuse by the major world powers is largely down to the incalculable risks of doing so *(especially given the perceived immorality of their use worldwide)*. But there are several other reasons too. Despite being relatively cheap to produce, unless they are stored under precise conditions, *'living'* biological weapons are liable to degrade much more quickly than *'inanimate'* chemical munitions *(making large scale storage both costly and extremely hazardous)*. In addition, even the most potent modern biological weapons engineered with fast infection rates could take hours or even days to incapacitate an enemy force. Indeed, whilst biological weapons can cause widespread devastation and lasting damage to a targeted area, their destructive potential lacks the immediacy of most chemical weapons. There is no doubt that a well-planned biological attack could easily destroy an entire city, but it also carries the potential for various undesirable consequences. For example, not only would an unconfined outbreak of weaponised smallpox or plague bring indiscriminate suffering to unintended victims in neighbouring communities, but person-to-person transmission could even lead to an unstoppable global pandemic.

The concept of using biological weapons is as old as civilisation itself, with the biotoxins from certain plant and animal species regularly employed *(often surreptitiously)* to kill people en-masse. Indeed the venom of snakes and arachnids, along with the poisonous secretions from certain frogs, and the toxic spores of parasitic fungi have all been used to deadly effect over the centuries. Insects too have also been employed offensively, with the subversive introduction of pests in order to destroy crops or attack livestock a comparatively common occurrence during the Middle Ages. Perhaps the deadliest examples of *'entomological warfare'* however involve the intentional release of infected fleas as a way to spread plague.

Transmitted via the 'Oriental rat flea', and caused by the bacterium *Yersinia pestis*, plague has been used on many occasions throughout history as a biological weapon. There are historical accounts from both ancient China and medieval Europe of plague-infected animal carcasses and human corpses being used to contaminate water supplies, or even fired directly at the enemy. Indeed there is anecdotal evidence to suggest that the Mongol tactic of catapulting infected corpses over the city walls during their protracted siege of Kaffa in 1347 was instrumental in the spread of *'Black Death'* across Western Europe. This, the second plague pandemic to hit Europe would go on to kill up to 60% of the continent's entire population. Like plague, Smallpox too has a dark history of being used as a terrifying weapon against civilian populations. In the mid-18th century for example, British colonial forces in North America during the 'Seven Years War' issued blankets infected with smallpox to native Americans in order to deliberately spread it amongst 'hostile' communities who, unlike the European settlers, lacked any form of natural defence against this virulent disease.

Spawned by the sciences of industrial warfare, 20th century research into new bioweapons intensified significantly throughout the 1930's. During the inter-war years, most of the world's major powers invested heavily in developing more resistant strains of deadly microorganisms with the aim of weaponising them. Culturing these 'living' weapons of mass destruction, military scientists now exploited viral agents such as *Variolae major (responsible for the spread of smallpox)*, and bacteria such as *Bacillus anthracis* ~ the cause of ***'anthrax'***. Whilst hundreds of different viruses and bacteria were trialled and discounted, anthrax, in particular, proved to be an ideal pathogen for further bioweapons research. Not only is it highly virulent, but anthrax spores are especially hardy and can even be freeze-dried before use *(making the decontamination of infected land very difficult)*. Primarily a livestock disease, it is not particularly contagious *(largely negating the concern of uncontrolled infection rates)*, yet if distributed widely enough, drug-resistant weapons-grade anthrax could easily be used to wipe out an entire targeted population.

Bioweapon research during this time did not solely concentrate on creating new strains of pathogenic microorganisms to weaponise. The exploitation of numerous species from across the taxonomic spectrum was considerable, with various plants, animals, fungi and bacteria all providing deadly toxins that were subsequently isolated and adapted for military use. Indeed by the 1940's **US** scientists had isolated the most toxic of all natural proteins ~ ***'botulinum toxin'***. Responsible for the rare but potentially fatal disease botulism, *clostridium botulinum (and several other closely related bacteria)* are commonly found in water and soil yet, under anaerobic conditions, will produce deadly spores that enable them to multiply. Approximately 15,000 times more potent than **VX** gas, within just a few years the **US** military had stockpiled enough of this acutely lethal neurotoxin to extinguish all animal life on Earth.

Whilst intensive research into biological weapons was being carried out by large military powers throughout North America and Eurasia during the 1930's and 40's, parts of East Asia would experience the true horrors of biological warfare for real. In 1937 Japan invaded China using conventional weapons but, as the conflict continued, biological weapons were increasingly seen as being cheaper and easier to use. The acceptability, by Japan, of using such weapons was made possible by an acute cultural indifference to the lives of foreign subjects. Indeed the ***'Imperial Japanese Army'*** were guilty of the most appalling war crimes against the civilian population on mainland China. Not only did they rape, torture and murder hundreds of thousands of people, but they deliberately transmitted highly contagious pathogens within numerous captured towns and villages. Diseases such as ***'bubonic plague'***, ***'cholera' 'typhoid'*** and ***'dysentery'*** were actively spread via contaminated water supplies and infected meat ~ with conquering forces often masquerading as being helpful whilst carrying out a programme of disinformation. Japanese forces employed *'death squads'* that warned of infection, but secretly propagated the disease themselves within the local population. Many isolated communities were targeted for experimentation, with sick inhabitants often anaesthetised and dissected in order to test their results, before having their 'infected' villages burned down. In this way many thousands of civilians were used as 'guinea pigs' for Japanese research into the effectiveness of different biological agents.

Over the course of World War **II** *(and the 'Second Sino-Japanese War')*, Japan's active biological warfare programme was responsible for killing well over a quarter of a million people. The Japanese military even developed the first *'plague bombs'* ~ ceramic containers filled with fleas collected from plague-infested rats. These were subsequently dropped over Chinese cities in order to spread the disease amongst their inhabitants. In one such plague attack on the city of Ningbo in Zhejiang province *(in 1940)*, a single cargo of fleas was known to have killed over 500 people. This, however, was just one of many biological attacks by Japanese Imperial forces on Chinese civilians during the Second World War. The extensive use of both biological and chemical weapons in the city of Changde, in Hunan province *(between 1941-3)*, for example, led to the agonising deaths of tens of thousands of people.

From early 1932 until the very end of the war, the Imperial Japanese Army conducted many thousands of experiments into the effects of different chemical and biological agents on live human subjects. Regarded as being both a scientific and wholly patriotic venture by the Japanese authorities, much of this abhorrent research was led by microbiologist and 'surgeon general' **'Shirı Ishii'**, who was instrumental in advancing the nation's considerable bioweapons capabilities.

At the heart of Japan's biological and chemical weapons programmes lay a secretive military establishment, somewhat misleadingly titled the ***'Epidemic Prevention and Water Purification Department'***. Whilst its public mission was indeed concerned with researching diseases and monitoring water supplies, its military objectives were far more sinister. Indeed it was primarily set up to turn virulent diseases into weapons of mass murder, with medical experimentation on living human subjects becoming commonplace in a number of its compounds. Established in 1936, its headquarters were based at the infamous ***'Unit 731'*** ~ a huge complex situated in the city of Harbin, in central Manchuria *(North-East China)*. Here thousands of prisoners were murdered in the name of scientific research.

By the start of the Second World War Japan had a large network of secret biological and chemical weapons research facilities throughout its Empire, where people of all ages and ethnicities were experimented upon. Alongside Unit 731, numerous other compounds were built to research new weapons of mass destruction, with other notorious sites including ***'Unit 1644'*** in Nanjing, ***'Unit 1855'*** in Beijing. and ***'Unit 100'*** near Changchun in Jilin province. Indeed the Imperial Japanese Army built military research centres all over East Asia and, by 1940, its well funded germ warfare programme had broadened considerably. Tests on live human subjects were now wide and varied, with countless grotesque experiments concocted to analyse the effects that different weapons have on the human body *(and mind)*. Comprising of captured *(largely Chinese)* soldiers and civilians *(as well as smaller numbers of Korean, Mongolian and Allied prisoners)*, the unfortunate victims were used in any number of different inhumane experiments ~ be they exposed to lethal doses of radiation, gassed with an array of poisons, burned or frozen by various means, strapped to centrifuges, or even eaten alive by different species of carnivorous insects. In total well over 10,000 people were murdered at these compounds during their years of operation, with detailed analysis of their deaths ultimately used to advance the military might of Imperial Japan.

Whilst the inhumane activities within these compounds were wide-ranging, researching and honing the effects of weaponised agents *(both chemical and biological)* remained the priority for most medical scientists at Unit 731. Referred to as *'maruta' (or logs)*, thousands of prisoners *(including pregnant women and young children)* were intentionally infected with different bacterial and viral pathogens before undergoing live vivisection *(often without anaesthetic)* ~ enabling military scientists to examine the progression of various diseases at different stages of infection. Many victims were taken to fields where they were tied to stakes and forced to look up before having a biological agent *(such as anthrax or plague)* sprayed upon them from overflying planes. Thousands of prisoners were effectively used as incubators, in order to cultivate stronger strains of deadly bacteria. Infected victims would often be chloroformed before having their blood forcibly drained from their bodies as a way to enhance the virulence of certain pathogens and create ever more potent strains. Indeed over 3000 prisoners were killed in this way by Japanese *'doctors'*. The military might of Imperial Japan was ultimately advantaged by its cultural disciplines ~ namely a learned ability to disengage from emotional stress, which appeared to Western observers as an almost psychopathic lack of empathy for human suffering.

The atomic attacks on Hiroshima and Nagasaki by ***'United States Army Air Forces'*** in 1945 put an abrupt end to Japan's inhumane research into weapons of mass destruction, and their clandestine biological weapons facilities were subsequently shut down. Although in its infancy, the Japanese programme was nevertheless quite advanced, with Western moral principles naturally preventing similar human experiments on American soil for example. Concerned that the Soviet Union would get their hands on over ten years of valuable Japanese research, immediately after the war the **US** military secretly removed much of the incriminating evidence ~ effectively exonerating Ishii and key members of his team in return for the complete disclosure of Japanese operations. Indeed the American government guaranteed hundreds of complicit scientists immunity from prosecution for war crimes in exchange for their full cooperation and assistance in integrating their work into America's own research and development programme ~ saving millions of dollars as a result. **US** scientists now worked on making biological weapons as destructive and effective as atomic weapons, with bioweapons development becoming an integral part of Cold War military planning *(both in the **US** and the Soviet Union)*. In fact the mutual paranoia that beset both sides during the Cold War led to an 'overkill' in their production. Despite the abhorrent suffering that bioweapons can bring, their feasibility was now reassured, with most biological warheads specifically designed to be used against enemy cities in the aftermath a nuclear attack ~ primarily as a way to eradicate survivors and prevent any hope of recovery.

Although experimentation was restricted to animal subjects, Allied research into biological weapons during World War **II** was also, nonetheless, just as active. In 1942 for example, serious concerns about Germany and Japan potentially using bioweapons against its forces, led the British authorities to begin field trials of anthrax in order to investigate whether it would be practical to use as an offensive biological agent. Having requisitioned the remote island of Gruinard off western Scotland to carry out their experiments, government scientists tested a number of anthrax bombs on eighty tethered sheep. Using the highly virulent *'Vollum strain'* which had been recently developed at ***'Oxford University'***, they found that the spores could contaminate entire cities for several generations ~ with potentially catastrophic consequences. If strategically targeted, weaponised anthrax was found to be up to a thousand times more effective than even the most toxic chemical agents that they currently possessed. Despite building anthrax bombs *(as well as preparing millions of infected 'linseed cakes' to be dispersed across German farmland)* in case the Nazis ever make a preemptive biological strike, Allied forces thankfully never resorted to biological warfare, and British research into weaponised anthrax was eventually abandoned.

Throughout the late 1940's and early 50's, the **UK** continued to invest heavily in developing biological weapons, with scientists from the Porton Down research facility in southern England directing a series of field operations to test diseases such as plague, tularaemia, and ***'brucellosis'***. Unlike the **US** and Soviet Union however, British involvement in the biological arms race was relatively short-lived, and by 1956 all offensive research was ended. Not only did the **UK** lack the huge military resources necessitated by the adversarial mindset of the rival superpowers during Cold War era, but the political will in Britain to fund such a programme was severely diminished. Reinforced by a strong sense of moral repugnance at the horrific injuries and scale of destruction that weaponised biological agents could cause, the production and possession of all biological weapons was eventually prohibited by British law in 1974.

Having had firsthand experience of developing and manufacturing highly virulent strains of deadly microorganisms for offensive military usage, Britain would become only too well aware of the environmental consequences of its field tests. Indeed it would take the British authorities almost fifty years and around 300 tons of seawater-diluted formaldehyde solution to successfully decontaminate Gruinard Island. Nonetheless the United States and the Soviet Union continued their research and development of new bioweapons for several more decades ~ reinforcing the predominant doctrine of nuclear deterrence during the Cold War *(and beyond)*: namely one of *'mutually assured destruction'*.

As a result of this self-perpetuating fear of military inefficacy, both the **US** and the **USSR** had extensive biological weapons programmes ~ despite the obvious risks involved. Indeed by the late 1960's, their combined annual budget for bioweapons research and development exceeded half a billion dollars. By now both sides had weaponised and stockpiled a wide range of different pathogens, whilst advances in military technology had led to the mass production of various cluster bombs and bomblets designed to disperse these offensive biological agents as effectively as possible.

Although **US** president **'Richard Nixon'** announced his intention to end America's offensive bioweapons programme in 1969, it would be another four years before stocks of any significance were destroyed. Ensconced in a network of military installations, research and development for America's biological weapons programme was coordinated from ***'Fort Detrick'*** in Maryland, with numerous testing facilities spread around the country. Indeed a wide range of microorganisms were investigated in places such as ***'Pine Bluff Arsenal'*** in Arkansas, ***'Dugway Proving Ground'*** in Utah, ***'Horn Island Testing Station'*** in Mississippi, and ***'Fort Terry'*** in New York. Besides refining established bacterial agents such as anthrax and plague, throughout the 1950's and 60's **US** scientists successfully weaponised viral infections such as ***'swine flu'*** and ***'Venezuelan equine encephalitis'***, as well as a variety of powerful biotoxins including ***'Staphylococcal enterotoxin B'*** and ***'ricin'*** *(a toxic protein from the castor oil plant which had originally been investigated during World War **I**).*

Covert field testing of these and other agents was extensive in America throughout the much of the Cold War, however, due to the very nature of biological weapons, many were substituted for less virulent strains or 'harmless' incapacitants. Over the course of the 1950's, for example, countless experiments were carried out using non-lethal surrogates, with thousands of people *(both military personnel and civilians)* unknowingly exposed to everything from mosquitoes and fleas to fungal spores and aerosolised bacteria. Despite strong refutation from the **US** government, far more deadly biological experiments were surreptitiously carried out overseas. Between 1951-52, for example, a series of small-scale 'live' tests were implemented under the cover of the Korean War. Targeting remote communities in the north, covert American units *(with assistance from scientists formerly from 'Unit 731')* were responsible for causing the outbreak of several diseases; including bubonic plague, cholera, smallpox and even ***'yellow fever'***.

The idea that the **US** conducted live bioweapon tests in places such as North Korea and Cuba has proved highly contentious, however there is no doubt that the testing of offensive agents on American soil was widespread. The single largest chemical and biological weapons experimentation project to be carried out in the West during the Cold War was ***'Project 112'*** which lasted from 1962-73. Run by the ***'United States Department of Defense'***, it primarily sought to improve the delivery methods and effectiveness of various chemical and biological agents, as well as to establish the vulnerability of targeted populations. As part of the project, a series of tests carried out by the **US** military during the 1960's and early 70's involved covertly releasing *'simulant aerosols'* in *(and over)* a number of American towns and cities. To simulate the dispersal and penetration of anthrax spores for example, refined strains of similar species, such as *Bacillus actrophaeus* and *Bacillus subitlis* were used for their distinctive pigments and high rates of sporulation. However, following a number of secretive urban tests using these and other simulant microorganisms, some targeted populations experienced marked increases in flu-like illnesses ~ ranging from ***'pneumonia'*** to ***'whooping cough'***.

By signing the 1972 ***'Biological Weapons Convention' (BWC)*** and ratifying it three years later, the United States officially ended its bioweapons program. However it continued to develop defensive biotechnology and conduct the spurious research and development of so-called 'non-lethal' biological weapons. The Soviet Union meantime also ratified the **BWC** in 1975 however, being such a secretive state, its military was able to continue offensive biological research without fear of unwanted media attention. Indeed with its activities firmly closed to any form of outside scrutiny, the Soviet military defied the **BWC** whilst its government's pretensions of compliance to international law went largely unchallenged.

In 1973, a year after signing the Biological Weapons Convention, the Soviet Union established ***'Biopreparat'*** ~ a vast biological warfare directorate that aimed to continue the nation's research and development of bioweapons unhindered by its new legal commitments. Biopreparat *(meaning 'biological substance preparation')* created dozens of secretive military establishments around the **USSR**, most of which masqueraded as civilian research centres that specialised in things such as biochemistry, virology and immunology. Under the guise of legitimate biotechnology institutions, Biopreparat allowed the Soviet military to produce, test and stockpile highly virulent strains of numerous pathogens that could be used should the Cold War turn into a full-scale conflict with the United States and its Western allies.

By the early 1980's the **USSR** had established a network of secretive facilities that specialised in biological weapons research, with dozens of Biopreparat laboratories and production centres spread around the country. The Soviet bioweapons programme was indeed formidable ~ with clandestine operations stretching from Leningrad *(home to the **'Institute of Ultra Pure Biochemical Preparations'**)* to Stepnogorsk in northern Kazakhstan *(site of the **'Technical Institute for Microbiology'**)*. Responsible for weaponising and stockpiling a wide range of pathogenic agents, Biopreparat scientists researched numerous bacterial diseases *(including **'Q fever'** and **'glanders'**)*, viral diseases *(such as **'influenza'** and **'rabies'**)* and deadly toxins *(ranging from ricin to **'T-2 mycotoxin'**)*. A natural byproduct from a clade of *Fusarium* fungi, **T-2** mycotoxin had a particularly interesting part to play in the history of Soviet biochemical weapons. With a lethal dose of around one milligram, it was implicated in the infamous *'yellow rain'* incidents which killed thousands of people during the Soviet-backed counterinsurgency campaigns in Vietnam, Laos and Cambodia in the late 1970's and early 80's.

Far from being eradicated, throughout the 1980's Soviet biological weapons became increasingly sophisticated. The decade saw the development of new delivery systems designed specifically for aerosolised pathogens such as smallpox, anthrax and plague *(which had themselves been engineered to resist vaccines, and survive harsh environmental conditions)*. Indeed genetic engineering was extensively used in the search for new types of bioweapon, and it enabled military scientists to develop ever more virulent strains of pathogenic microbes that were already part of the Soviet arsenal. The incubation periods of *'viral haemorrhagic fever'* agents *(including those that cause **'Rift Valley fever'**, **'Marburg'** and **'Ebola'**)* for example, were lengthened ~ significantly increasing their infection rates. New bioengineered weapons that combined multiple pathogens were also developed. These included munitions designed to disperse diphtheria with plague, anthrax-diphtheria, and ***'ebolapox'*** ~ a hybrid Ebola-smallpox agent. By the mid-1980's even ***'HIV'*** was investigated with a view to weaponising ***'AIDS'***.

Due to the sheer scale of Biopreparat, combined with poor safety standards *(and the endemic nature of neglect during the Soviet era)*, there were inevitably a considerable number of deadly accidents throughout the **USSR**. For example, in 1971, at

'Aralsk-7' *(a biological weapons testing centre on Vozrozhdeniya Island in the Aral Sea)*, an accidental release of weaponised smallpox resulted in the infection and deaths of several people in the nearby town. Human error also led to an infamous accident in 1979, at the biological research compound ***'Sverdlovsk-19'*** just east of the Central Urals. Here a highly virulent strain of antibiotic-resistant anthrax escaped due to a misplaced exhaust filter ~ killing over a hundred people working in the vicinity. Had weather conditions been less favourable, the wind could have easily carried the anthrax spores to the nearby city of Sverdlovsk *(now Yekaterinburg)* which would have led to hundreds of thousands of casualties. As it was, this deadly incident sent the Soviet propaganda machine into overdrive. with communist officials seriously understating the scale of the accident, which itself was blamed on contaminated meat.

As a result of this accidental release of weaponised anthrax, large parts of the programme at Sverdlovsk-19 were either closed down or moved elsewhere. Indeed, in order to conceal Soviet noncompliance of the Biological Weapons Convention, records pertaining to operations *(and the accident itself)* were shredded and evidence was removed from the site. In an attempt to hastily destroy some of the stockpiles, the powdered spores were mixed with bleach, with hundreds of tons of anthrax slurry transported to a dumping ground near Aralsk-7. Here they were buried in enormous pits which invariably contaminated the land for decades.

Even after the fall of its communist empire, Russia retained a highly secretive bioweapons programme, and continues to violate the **BWC**. Whilst a number of facilities *(including Aralsk-7 and Sverdolvsk-19)* were abandoned with the collapse of the Soviet Union, others remain to this day. These include major establishments such as the ***'Institute of Applied Biochemistry'*** at Omutninsk in Kirov Oblast ~ a civilian facility specialising in the research and development of pesticides which also has provisions for bioweapons production. Another is the ***'Vector Institute'*** in the urban locality of Koltsovo, southwestern Siberia ~ one of the world's two remaining official repositories of smallpox *(the other being at the* ***'Centers for Disease Control and Prevention'*** *in Georgia,* ***USA****)*.

A well-planned biological attack on a major city today *(be it a military strike from a foreign state aggressor or an act of homegrown bioterrorism)* could have a devastating effect on modern civilisation. Alas, the assiduous efforts to develop bioweapons in America and Russia throughout the latter half of the 20th century has made it comparatively cheap and easy today for other nations *(or well-funded terrorist organisations)* to copy. In fact there are countless possible scenarios from which a biological attack could occur ~ with the aggressive use of anything from anthrax and botulinum toxin, to cholera and plague potentially capable of bringing about civil collapse. Indeed *(with the vectors of plague endemic to many parts of the world)* aerosolised ***'pneumonic plague'*** remains one of the most significant bioweapons threats to modern civilisation. Smallpox too, still poses a clear and present danger to humanity. With naturally occurring smallpox being globally eradicated in the mid-1970's, the present human population *(no longer having an established resistance to the disease)* would be particularly vulnerable to a weaponised smallpox attack.

Whilst both the United States and Russia renounced the use of biological weapons and officially shut down their respective programmes decades ago, the further development of these horrific weapons still continues within the former Cold War superpowers *(and elsewhere)*. This occurs both directly *(as covert research into biological warfare)*, and indirectly *(as unrelated medical advances that attract military involvement)*. By 2013, for example, **US** microbiologists had successfully isolated a new variant of botulinum neurotoxin *(initially known as 'serotype **H**')* ~ the most toxic substance known to science. With as little as two billionths of a gram enough to kill an adult human, the military applications of this 'hybrid neurotoxin' were swiftly investigated. In the same year, Russian scientists had managed to recreate the smallpox virus using *'artificial gene synthesis'* ~ effectively nullifying the finality of the global extermination of this highly virulent killer. Moreover, with the field of synthetic genomics advancing rapidly *(along with ability to purchase the **DNA** sequence of any existing pathogen on-line)*, it is becoming increasingly easy to resurrect old diseases, or even create completely new ones. Alas, the likelihood of someone, somewhere contriving to unleash a new 'biological super-weapon' increases as the practice of recombining artificial chromosomes becomes more widespread. Indeed, with each passing year, the ever-present dangers of bioterrorism become greater, with the growing potential for weaponised pathogens designed in a 'back-street' laboratory to be as deadly as a nuclear attack.

Although the research and development of **WMD**s is not as sophisticated as it is in the **US**, Russia, and China, a number of smaller *(largely 'developing')* nations continue to sanction atomic, chemical and biological technologies to expand their military capabilities ~ without conscience. North Korea and Syria, for example, not only have stockpiles of deadly chemical agents such as, sarin, **VX**, and mustard gas, but also retain stocks of various bioengineered diseases; including anthrax, cholera and botulism. Then there's Israel and Iran who clearly have the ability to launch a chemical or biological offensive, but successfully retain a certain ambiguity concerning the extent of their **WMD** programmes. Countries such as Iraq and Libya were, until relatively recently, actively seeking to advance their unconventional military capabilities until their respective programmes were forcibly shut down through international pressure. Other nations, including Pakistan and South Africa, voluntarily closed their chemical and biological weapons programmes decades ago, but maintain facilities that could be swiftly adapted to produce weaponised agents. Indeed any country with advanced biological research programmes could readily produce bioweapons should they feel the need to consider that military option. Thus far only Japan has openly used biological weapons in modern warfare, but the *'poor mans' nuclear bomb'* is another vicious legacy of mankind's capacity to disregard all life in the pursuit of victory. So long as we are capable of experiencing the emotion of hatred towards our perceived enemies, the research and development of offensive nuclear, chemical, and biological technologies will continue.

The perceived military might of a country does not solely rely on the physical size of its armed forces. Whilst numbers *(in terms of personnel and weaponry)* are most certainly a factor in assessing any nation's military capabilities, so too is the size of its defence budget. This not only determines the power afforded to its military institutions, but also how advanced its incumbent weapons systems may be. It stands to reason that a country which spends billions of dollars annually on improving its military technology is more likely to win a war against one whose armed forces are poorer and less well equipped. Indeed, with greater investment, any army is likely to improve its ability to outmanoeuvre potential enemies, and the whole ethos of warfare is to be one step ahead of the enemy.

The ideal scenario for a nation drawn into military conflict is to win swiftly and with as few casualties as possible *(at least on their own side)*. It is therefore in the interests of any country for their armed forces to use the most advanced weapons technology available. This gives combatants a greater chance of making a decisive move, which *(by severely limiting their enemy's ability to respond)* could ultimately prevent a reciprocal attack. It is precisely this mindset *(rather than ideological belief)* that wins wars. As a result, many countries place enormous investment in military research and development, with various agencies around the world focusing on developing weapons systems that could be used in future wars.

Even in times of peace, a vast majority of countries around the world continue to invest heavily in weapons of war in the name of 'national security'. Moreover the potential threat of a future war *(along with the irresistible desire to improve military technology)* is effectively the 'mother of invention' ~ ultimately contributing to countless different aspects of civilian life. Indeed most modern armed forces around the world continually update their active weapons systems in order to keep up with technologies that make older systems obsolete. It is a process of innovation which has also benefited modern society enormously over the years ~ giving us everything from essential radar and satnav systems to jet engines and the Internet. With their well-funded military machines, the world's most powerful nations today possess sophisticated armouries 'boasting' state of the art weaponry ~ the creation of which lies far beyond the realms of contemporary civilian technology.

Whilst military investment continues to advance *'conventional'* weapons technology in many countries around the world, the future development of *'unconventional'* weapons of mass destruction is not so straightforward. The most significant improvements to nuclear weapons, for example, had already taken place during the 1970's and 80's, when tactical-use bombs were refined to their conceivable limits. Indeed both the miniaturisation of nuclear warheads and the maximisation of neutron radiation from nuclear blasts had been effectively achieved. Limitations to the sheer size of nuclear weapons had been determined only by practicality, and this landmark was reached in the early 1960's with the detonation of the Soviet Union's ***'Tsar Bomba'***, whose yield actually had to be reduced in order for it to remain viable as a weapon.

Ultimately all nuclear weapons *(be they a one hundred megaton hydrogen bomb or a 10 kiloton neutron bomb)* will cause indiscriminate destruction to any targeted area and, for the most part, further refinements to nuclear technology can bring no greater military advantage. Indeed only one area of nuclear engineering has continued to advance the development of such destructive weapons. Ongoing military research continues to explore a specific phenomenon of nuclear explosions ~ the electromagnetic pulse *(or **EMP**)* which can actually induce geomagnetic storms and temporarily distort the Earth's magnetic field. Also known as a *'radioflash'*, the instantaneous burst of gamma radiation that accompanies even the smallest nuclear explosion can be used to ionise the upper atmosphere and generate a highly disruptive pulse of electric current that is capable of destroying a wide range of essential electronic equipment far beyond the blast radius of the bomb itself.

When detonated at high altitude *(approximately anywhere between 15-25 miles above sea level)*, even a comparatively small nuclear device can cause widespread devastation to vital electronic infrastructure. Further development of these so-called ***'super EMP weapons'*** has continued into the 21st century, with computer-simulated attacks realising high altitude bombs which can produce intense electromagnetic pulses capable of destroying electronic systems on a 'continental scale' whilst producing minimal radioactive contamination. Causing power plants to explode, and instantly annihilating all forms of electronic communications for thousands of miles around, an enhanced nuclear **EMP** attack, using just a single weapon, would wreak total havoc on any targeted nation ~ potentially crippling its civilian infrastructure for many years. Simply by shutting down the essential services so relied upon by millions of people, the atmospheric detonation of a nuclear **EMP** device would likely cause widespread starvation. Indeed in 2017, the ability of North Korea to launch a nuclear attack on the **US** mainland caused immense apprehension, with concern that even a crude **EMP** bomb could ultimately kill millions of **US** citizens over a protracted time span.

Although not new, the idea of developing a nuclear weapon specifically to generate a powerful electromagnetic pulse *(as its primary function)*, was never really regarded as a practical option for military investment during the 20th century. Throughout the Cold War, for example, the main focus for both nuclear superpowers always concerned the size of their arsenals and the strategic positioning of their warheads. Indeed the use of effective **EMP** devices was not seen as a plausible option in the event of a nuclear war. However technological advances during the early 21st century has brought such weapons into reality, and today they exist in relative abundance in the nuclear arsenals of Russia, China and the **US**.

Taken to the extreme, it has even been suggested that super **EMP** weapons are the consummate *'doomsday devices'*, with one particular 'conspiracy theory' putting them at the heart of a potential attack on global civilisation. It suggests that, under immense strain from overpopulation, growing pollution, diminishing natural resources and the continuous outbreak of major regional conflicts, modern civilisation is becoming increasingly fragile. Therefore, civilisation cannot continue in its current form indefinitely, and the inevitable realisation of its imminent collapse will ultimately catalyse a revolt by the world's wealthiest and most influential individuals. In such a scenario, the imminent failure of modern civilisation would present stark choices to those with the power to choose self-preservation over the lives of billions of ordinary people. Should there ever be a coup by the 'global elite' in order to negate their own demise, the use of nuclear **EMP** attacks *(co-ordinated with targeted cyber attacks on critical services)* would ensure the highest fatality rate amongst the human population whilst minimising long-term damage to the environment - thus preserving the planet for future generations of a privileged few.

In any event nuclear weapons, however they are potentially used, remain as big a threat to modern civilisation now as they did at the height of the Cold War. Moreover, the research and development of unconventional weapons is not just restricted to advancing nuclear warfare technology. Amongst the international community however, there is a far deeper sense of immorality surrounding the use of chemical and biological weapons than there is regarding the continued possession of nuclear ones. As a result of their perceived illegitimacy, no nation would openly admit to possessing chemical or biological weapons, and continued research into these non-nuclear **WMD**s is largely repressed in most countries which are not controlled by hard-line military regimes. Yet whilst the stockpiling and use of such weapons may be internationally outlawed, many armouries around the world are already awash with weaponry that could be readily adapted to carry deadly chemical or biological agents *(which are themselves relatively easy to reproduce)*. Like nuclear bombs however, the 'deterrent' aspect of using them lies in the fear of provoking a reciprocal response. Indeed the use of such weapons against an enemy capable of mounting an equally fearsome reprisal would be foolhardy, and their 'non-use' in active conflicts has *(for the most part)* held out ~ with global peace being maintained despite the continuous eruption of vicious regional wars.

The evolution of the world's most powerful non-nuclear weapons has now become increasingly influenced by aberrant military innovation. Indeed the development of **WMD**s throughout the last century was primarily driven by the sheer level of destruction that they could bring to an enemy. A predominant strategy for some of today's great military powers however is to develop weaponry capable of exacting more 'surreptitious' methods of mass destruction. A considerable proportion of military research in Russia, the **US** and a number of other nations, for example, is geared towards investigating powerful new weapons that are less indiscriminate than current **WMD**s ~ but no less destructive. The underlying military ethos being to invent ingenious new ways to kill an enemy en-masse without fear of reprisal. One of these lines of investigation concerns the development of ***'genetic weapons'***, with the **US *'Department of Defense'***, for example, investing heavily *(over $100 million by 2017)* in projects concerning 'gene drive inheritance', 'protein design', and 'artificial gene synthesis'. Responsible for exploring new and emerging technologies solely for their potential military applications, ***'DARPA'*** *(the 'Defense Advanced Research Projects Agency')* has ploughed considerable resources into investigating the practicalities of weaponising various genetic technologies.

Over the past few decades, genetic sciences have advanced at considerable at pace, and a number of workable *'genome editing'* techniques have been developed. The most effective methods involve using an engineered nuclease to precisely target a desired mutation. Developed in the early 2010's, ***'CRISPR-Cas9'*** is *(to date)* perhaps the most practical technique; vastly increasing the speed and efficiency of countless genetic engineering projects. **CRISPR** *(Clustered Regularly Interspaced Short Palindromic Repeats)* is a repeating sequence of bacterial **DNA** dedicated to resisting viral attacks. Interspaced with variable fragments of viral **DNA** to which its host cell had previously been exposed, **CRISPR** sequences protect certain bacteria from future attacks by directing specific proteins to recognise and cleave invading **DNA**. By using a synthetic 'guide **RNA**' to control the associated protein *(in this instance 'Cas9', which essentially updates the bacterial immune system)*, scientists can effectively direct **CRISPR-Cas9** to modify the genome of any living species. As a tool of genetic manipulation, it has proven extremely useful in many fields of genetic research and has shown to have numerous clinical and agricultural benefits. Indeed, besides enhancing several branches of medical science *(from biomedicine to gene therapy)*, **CRISPR-Cas9** has the potential to improve human health in countless other ways. It could radically reduce human susceptibility to innumerable afflictions and increase longevity. As an environmental tool, it could be adapted to create yeasts that produce efficient new biofuels, or bacteria that consume persistent pollutants. As a highly effective method of germline editing, **CRISPR-Cas9** *(if used with extreme caution)* could even be employed to eliminate harmful invasive species or completely eradicate diseases such as malaria.

Of course, technologies such as **CRISPR-Cas9** can also be used with malign intent, and are readily utilised for investigating effective genetic weapons. In fact, by improving our ability to manipulate **DNA** with great precision, **CRISPR-Cas9** has brought the concept of warheads containing bioengineered agents that can actually alter the human genome much closer to reality. A comparatively new line of investigation for military research in several countries, genetic warfare could involve horrific weaponry capable of causing any number of maladies. By controlling enzymes that can actually change the nucleotide sequence of **DNA**, military scientists have already developed prototype weapons capable of causing artificial mutagenesis within living organisms. Indeed those who strive to possess such weapons would potentially have the ability to alter the genetic inheritance of their enemies *(or the plants and animals they depend on)*.

A highly effective tool of 'ethnic cleansing', genetic weaponry could be used to engineer almost any trait *(which could be made to manifest immediately or after many years)*. They could, for example, cause a predisposition to diseases such as cancers and forms of dementia, or inflict any other type of physiological disorder upon a targeted community ~ from organ failure to deadly food intolerances. The possibilities are endless. Imagine a nation which possess a wide range of weapons tailored to inflict specific genetic defects. Such weapons could be used surreptitiously to precipitate 'minor' physical afflictions *(from hair loss to weight gain)*, trigger dangerous disorders *(such as persistent vomiting and intractable diarrhoea)*, or instil emotional ones *(such as inherent cowardice or a propensity for sudden violence)*. In fact they could be used to induce any form of mental disorder ~ from severe depression to psychosis. They could affect sexual orientation, or even induce paedophilic tendencies ~ thus creating a 'reason to hate' potential enemies. Furthermore a 'genetic attack' on an unsuspecting enemy could bring about undesirable traits that are either acquired or hereditary. It could potentially be used to sterilise an entire population or cause detrimental genetic modifications that blight future generations. Through targeted gene mutation, debilitating disorders such as Down's syndrome, and indeed any physical birth defect *(ranging from dysmelia to* *congenital heart disease)* have the potential to bring suffering to 'enemy populations' for many generations.

Perhaps the most disturbing aspect of this is that, as years pass, genetic technologies will gradually become cheaper and more readily available ~ making it easier for those who wish to possess such weapons to do so. Indeed one of the greatest fears concerning genetic weaponry is that it won't just remain a contrivance of wealthy state players, but could fall into the hands of *'amateur biohackers'*. In a world where hatred has become amplified through modern science, there are numerous groups and individuals with extreme ideological beliefs for whom hacking the human genome could somehow serve their warped credo. Whether it be to create *'ethnic bioweapons'* designed to target certain people or artificial viruses which indiscriminately attack anyone they encounter, the potential for hostile genetic technology is of growing concern. Furthermore advances in *'digital biology'* over the past few years has raised the prospect that computers could even be used to make precise changes to the genomes of any targeted population, opening up the possibility that artificial intelligence *(or AI)* could eventually alter humanity itself.

Since its re-emergence as a serious discipline at the very end of the 20th century **AI** has progressed significantly, and now contributes enormously to every other branch of computer science. Likewise the influence of **AI** within modern society is growing considerably, as is the dependence of the modern world upon it. Directed by complex algorithms, many programmable machines now have the ability to learn from experience and adapt accordingly in order to complete their given tasks. With each passing year, machines are getting ever more adept at problem solving, and can now match and even surpass humans in numerous fields of endeavour. Indeed, in many cases **AI** controlled devices can now react faster and with greater accuracy than their human counterparts ~ threatening to revolutionise many aspects of the modern world *(from the automotive industry to the judicial system)*. By the mid-2010s, **AI** and robotics had already become essential in numerous areas of civilian life in the developed world; ranging from medicine and engineering to finance and security. Present in everything from smartphones to modern cars, **AI** is now routinely applied to language translation and facial recognition, it is used to categorise human behaviour for the purposes of advertising and gaming, and *(via 'computational creativity')* has even enabled machines to become expressive through the once 'exclusively human' concepts of art and music.

The most advanced **AI** systems are presently based on *'neural networks'* ~ where computational values are processed by nodes *(or 'artificial neurons')* in a similar way that biological neurons process information within living brains. With numerous computer scientists attempting to electronically simulate human cognitive functions, one aim is to build self-learning machines which can 'objectively' assess their situation and 'subjectively' react to it without pre-programmed instructions. The ultimate goal for many scientists currently working in this field is to achieve *'artificial general intelligence'*. Indeed the idea that machines could eventually attain the ability to 'reason' through precise mathematical simulation of human intelligence *(and therefore surpass our own abilities)* is certainly no longer confined to the realms of science fiction. At the point when 'all-thinking' **AI** systems become indistinguishable from human thought *(passing all contrived means tests)*, then truly 'intelligent machines' would no longer be considered the *'philosophical zombies'* that embody even the most advanced computers today. However this eventual self-awareness *(or 'technological singularity')* of artificially intelligent systems opens up all sorts of ethical dilemmas.

The most demonstrable examples of unethical uses for this technology concern the design of malevolent **AI** software which is programmed for immoral, criminal or otherwise malicious intent. Some **AI** systems are already capable of influencing human activity ~ having been programmed to spread disinformation through manipulating news agendas or by creating authentic looking *(and sounding)* 'fake videos'. Another nefarious use of **AI** systems is for *'automated hacking'* ~ with activities ranging from *'spear-phishing'* to breaking *'message authentication codes'*. There is also a growing threat from **AI**-driven software agents *(or 'bots')* designed to overwhelm **IT** systems with malware in order to bring down targeted websites and severely damage the organisations that run them. Indeed **AI** technology can seriously compromise cybersecurity in numerous ways.

AI is, of course, being used to great effect within all modernised armed forces, and it has numerous military applications ~ employing many thousands of programmers and engineers around the world to work in various fields. It is used extensively in military research; and is particularly valuable for test simulations and 'virtual war games'. Furthermore it has already played a direct role in *'cyber warfare'* ~ with Russia's notorious use of **AI** to co-ordinate various acts of espionage, sabotage and propaganda against other countries. However **AI** software is not only useful for carrying out anonymous acts of *'cyber terrorism'* or *'political manipulation'*, but it can be turned into a powerful weapon in its own right ~ capable of killing many millions of people. Russia, for example, has also invested in developing a weaponised computer program with the potential to destroy the entire electronic infrastructure of a nation at the click of a button ~ crippling essential industries *(such as communication, transportation and energy)* which are critical for modern existence. Indeed, with each passing year, **AI** is increasingly being co-opted into new weapons systems, particularly in America, Russia and China where huge military investment and vast resources have advanced the scope of artificial intelligence considerably. Here, **AI-**powered 'navigation' and 'strategic planning' systems are becoming more prominent within various military operation networks, as are autonomous intelligence-gathering systems *(including a growing number of highly sensitive photoelectric spy devices).* Moreover, with rapid advances in the field of 'cognitive robotics' over the past few decades, we are heading inexorably toward the development of specific ***'AI weapons'*** that can make their own decisions regarding whether and when to strike.

Along with the explosion of **AI** technology throughout the 2010s came a rush to develop new kinds of **AI**-powered weaponry, with several major world powers vying for military superiority in this field. Indeed this game-changing technology has opened up a new arms race, and competition to create increasingly sophisticated **AI** systems is likely to bring about entirely new kinds of **WMD**s. Today, there already exists a huge range of military hardware that could be considered **AI** weaponry; ranging from machine gun posts operated by neural networks, to microdrones armed with deadly payloads which are guided by *'swarm intelligence'*. The decade also saw the rapid development of **AI**-controlled *(large scale)* missile-drones as well as a wide range of lethal hypersonic weapons. In 2018, for example, Russia announced that it had developed a fully operational low-altitude, nuclear powered missile system ***('Sarmat')*** whose **AI** components enable it to 'precision steer' at an almost unimaginable speed. Indeed, with echoes of the long abandoned **US** ***'SLAM'*** project from the 1950's, this Russian state-of-the-art missile system is completely impervious to all American defences.

Investment in *'lethal autonomous weapons systems'* today is huge, and regardless of what international laws may eventually prohibit or restrict their use in the future, numerous military institutions around the world are currently free to develop fully autonomous weapons. Indeed by the mid-2010s a number of countries were already producing 'intelligent munitions' which could adjust their course after being fired for maximum *(or selective)* impact. Unfortunately we are inexorably heading towards a nightmarish future where highly efficient *'killer robots'* are capable of selecting and engaging their targets without human oversight. Furthermore, when you factor in the obvious military applications for other groundbreaking technologies to have been developed during the 2010s *(such as **'synthetic genomics'** in the **US** and **'quantum encryption networks'** in China)*, then the continued exploitation of **AI** for the purposes of warfare will likely become even more far-reaching. Should military **AI** technology become so potent that it could dictate the outcome of all future wars, then it is the enigma of 'human rationale during wartime' that is likely to be the undoing of our species. Self-learning machines which lack the shared qualities that define the human experience would have a different perception of morality or 'common-sense' ~ invariably drawing their own conclusions and acting accordingly.

By increasing the efficiency of the various 'tools of death' that are employed during war, technological advance *(historically speaking)* only serves to intensify its ferocity. This was particularly evident in the horrific wars that took place at the dawn of the industrial age ~ with the introduction of inventions such as machine guns, torpedoes, bombers and tanks. Indeed scientific progress, no matter how advantageous to human well-being, can be equally applied to the technologies of destruction and has yet to actually prevent suffering and conflict. Alas the introduction of sentient **AI** systems onto the battlefield over the coming decades will likely take human suffering to a whole new level.

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vii.

(Variations on M.A.D.)

Were just one nuclear warhead to be used in anger *(wherever the conflict)*, it is almost certain that the international community would be unable to prevent a rapid escalation in hostilities which would likely descend into a global nuclear war. Indeed the only reason that the Second World War did not continue after **US** forces detonated two atomic bombs over Japan in 1945 was that no adversaries of America could match the awesome power that they had unleashed. It is only when the **USSR** successfully demonstrated its own nuclear capabilities four years later that a new arms race ensued ~ and it was one that had the potential to destroy all advanced life on Earth.

In the decades after the Soviet Union's acquisition of atomic weapons in 1949, a number of other countries successfully developed their own atomic weapons programmes ~ with the **UK** *(1952)*, France *(1960)*, China *(1964)* and Israel *(1966)* all joining the exclusive 'nuclear club'. Furthermore, following America's successful detonation of a fully-deployable fusion bomb in 1954 *(which had an explosive force of about a thousand times greater than the early fission bombs)*, all of the aforementioned states would go on to advance their nuclear arsenals and build these unimaginably powerful hydrogen bombs. Despite the ***'Nuclear Weapons Non-proliferation Treaty' (NPT)*** passing into international law in 1970, further research and development has not been restricted to these six nations ~ with non-signatories India *(1974)*, Pakistan *(1998)*, and North Korea *(2006)* all successfully undermining the spirit of the treaty and building their own nuclear defence systems.

Although, since 1945, there have been no conflicts on quite the same scale as World War **II**, the peaceful coexistence of various nuclear powers has been somewhat fractious, adding a dangerous edge to many international affairs. Indeed during the Cold War and beyond, the spread of nuclear weapons technology has sporadically threatened continuing global stability. The 'Cuban missile crisis' in 1962 was a prime example, as was the 'Sino-Soviet split' in the early years of the decade ~ leading to the development of China's own nuclear programme. The end of the Cold War itself was particularly subversive, with the fall of the **USSR** in 1991, for example, creating three independent nuclear states virtually overnight. But whilst Ukraine, Belarus and Kazakhstan turned over most of their weapons to Russia *(in return for guaranteed territorial rights)*, the chaotic collapse of the Soviet Union had encouraged widespread corruption and seriously compromised its nuclear security. As a result, countries that sought to contravene the **NPT** and develop their own nuclear weapons could more readily do so, with Pakistan and North Korea notably able to procure both Soviet nuclear technology and fissile material.

Whilst Pakistan conducted its first public nuclear test, ***'Chagai-I'***, in 1998 *(as a direct result of India's nuclear tests two weeks earlier)*, its atomic weapons programme had been in operation since the early 1970's and was already well advanced. In fact, like Russia, Pakistan played a significant part in proliferating nuclear technology and materials around the world, with its government quietly cognisant of several nuclear scandals. Throughout the 1990's Pakistani nuclear physicist **'Abdul Qadeer Khan'** *(a senior figure within the country's atomic bomb project)* had surreptitiously sold nuclear technology *(such as gas centrifuges and other enrichment components)* to several countries. These included North Korea, Libya, and Iran; whose ambitions not only compromised the **NPT** but seriously threatened the global nuclear 'status quo'.

Although not a signatory to the **NPT**, Pakistan's apparent disregard for 'Western nuclear sensitivities' has resulted in an unusual security alliance with the United States. Despite pardoning Khan in 2004 *(even though his actions were considered to be a serious threat to both Israel and the wider Middle East)* Pakistan was a nuclear power that sat in a geopolitical hotspot, and the **US** was keen to avoid any collapse of its Westernised armed forces. American concern about the security of Pakistan's nuclear arsenal was so great that, in 2001, it started providing assistance to protect the country's nuclear integrity and defend its facilities from the omnipresent threat of being overrun by Islamic militants. Indeed the increasingly paranoid attitude of **US** authorities concerning the dissemination of nuclear technology in the region was directly responsible for the tragic invasion of Iraq in 2003. Besides toppling Iraqi dictator **'Saddam Hussein'**s illiberal military regime, the invading **US** and coalition forces aimed to destroy nuclear facilities as well as stockpiles of biochemical weapons that simply did not exist. Alas this Western assault on Iraq's sovereignty only served to increase the resolve of other countries *(such as North Korea and Iran)* that <u>were</u> actively pursuing nuclear weapons.

Across the Northern Hemisphere there are around 13,000 nuclear warheads that are presently either deployed in active service or simply decommissioned and sat in storage. Whilst this may be far fewer than at the height of the Cold War, the fact remains that there are today innumerable ways that a pivotal event somewhere in the world could escalate into a full blown nuclear conflict. Indeed there are currently numerous international and regional situations that have the potential to spark a nuclear incident that could dramatically change the course of human history.

Besides the re-emerging air of belligerence between old Cold War rivals, several unfolding events around the world in recent decades have exemplified the problems of proliferating nuclear weapons technology. The ongoing dispute between India and Pakistan over Kashmir is one such volatile situation, whilst the unperturbed resolve of North Korea to build an intercontinental ballistic missile system capable of reaching the United States has had a profound effect on international diplomacy and accord. Indeed throughout East Asia, bitter historic conflicts have led to an uneasy coexistence between various neighbouring states, with China's influential military expansion, for example, causing growing alarm in places such as Japan, Taiwan and South Korea. Then there's the irrepressible tension of the Middle East where erupting wars continue to create a complex entanglement of allies and enemies. Here, both Russia and the **US**, *(along with Britain, France and several other Western powers)* have a vested interest in the outcomes of various prolonged and bitter conflicts. Aside from major wars in places such as Syria, Iraq and Yemen, regional power struggles continue to threaten the fragile peace elsewhere in the region. Iran's nuclear ambitions, for example, could prompt Israel *(or even the **US**)* to unilaterally strike nuclear facilities that it suspects of producing weapons *(despite Iran appearing not to have broken an international agreement designed to reduce its stockpile of enriched uranium)*. With Russia *(a formidable ally of both Syria and Iran)* also demonstrating its growing influence in the region, the Middle East remains at the centre of international discord.

Perhaps the greatest danger currently of a nuclear attack has resulted from the ongoing Russo-Ukranian War. Having annexed Crimea and armed a pro-Russian insurgency in the Donbas region of southeastern Ukraine in 2014, Russia's full-scale invasion of the country, in 2022, marked the first time in history that a nuclear state had *(in all but name)* declared war on a former nuclear state. As part of the Soviet Union until its dissolution in 1991, Ukraine was home to almost a third of the country's nuclear weapons stockpile until it destroyed its arsenal *(in accordance with the 1994 '**Budapest Memorandum**')* in exchange for financial compensation and national security assurances which were aimed largely from its larger neighbour to the east. Now a fully independent sovereign state, Ukraine, unlike its northern neighbour Belarus, forged increasingly Western ties which, by the 2010's, directly threatened '**Vladimir Putin's** ideological vision of Russia as a revitalised military superpower. However, with Western nations aiding Ukraine's valiant war efforts, its unexpected success on the battlefield has completely changed the dynamics of this conflict. Unfortunately Russia's particularly poor military showing and its belligerent rhetoric have considerably increased the likelihood of tactical nuclear weapons *(or other unconventional **WMDs**)* being deployed at some point in this war by an increasingly desperate Kremlin.

Yet vicious regional wars and bellicose diplomatic disagreements involving the **US**, Russia and China, are not the only incidents ultimately capable of leading to nuclear conflict. A catastrophic accident involving the unintentional detonation of a nuclear warhead has just as much potential to destroy modern civilisation as a deliberate and calculated attack. Either could end decades of world peace with an outpouring of nuclear rage. In fact, any future nuclear disaster needn't even be initiated by an act of human aggression at all. Indeed everything from a deadly viral pandemic to rapid environmental destruction could put us on an irreversible path towards mutually assured destruction.

After centuries of plundering both land and sea, we are faced with ever depleting natural resources ~ including essential commodities such as fresh water and crude oil. When you consider that widespread deforestation and pollution have resulted in degraded soils, rising ocean acidity and an increasingly toxic atmosphere, the stresses on modern civilisation have never been greater. As a result, human discord and regional conflicts continue to spread around the world, with civil breakdown particularly prevalent in poorer areas that endure climatic extremes or historic unrest. Moreover, if we continue to be led by a collective mindset where individual greed and national pride validate both our savage exploitation of the natural world and a hateful distrust of other people, we will inevitably reach a crisis point where human suffering outweighs the benefits of modern society ~ and direct military confrontation between the world's powerful nuclear states becomes irresistible.

Human civilisation *(like life itself)* is extremely fragile. Our very existence relies on the continuing co-operation between competing economies that are largely powered by different cultural attitudes and social norms. Supporting vast trading networks that benefit the lives of many millions of people around the world, modern civilisation has created a unique human environment upon which almost all of us now depend for our very survival. Indeed international co-operation has enabled our species to flourish, despite the damaging setbacks of war and disease. Yet this globalisation of human knowledge and ideas has also created new dangers that exacerbate our most malign social behaviours and cultural differences.

Whilst the pursuit of wealth is the driving force behind every economy, it is our society that shapes our collective identity which in turn manifests itself as a 'sovereign nation' ~ and it is the leaders of our countries who decide whether we are at peace or at war. Unfortunately, over the first decades of the current century, '*social liberalism'* has weakened considerably within many countries, as the polarisation of various belief systems has given way to increasingly hard-line attitudes towards foreign ideologies. Observed as right-wing '*neoliberalism'* in the west, and '*autocratisation'* in the east, this can only serve to increase the likelihood of war.

The Western mindset values individual freedom, and regards liberal democracy as a social panacea that could potentially bring lasting peace and stability across the world, but this perspective is not shared by everyone. In countries where the authorities are controlled by hard-line autocratic governments, individual rights are expendable, and citizens are ultimately expected to revolve their lives around the collective power of the state.

Although the habitual comforts of life within a Westernised democracy may be susceptible to the occasional economic downturn, prosperity amongst the population, generally speaking, is much greater. Society here embraces the culture of free market competition as a way to generate enormous personal and corporate wealth. Traded through global financial markets *(which are ultimately powered by greed and self-interest)* this wealth has enabled Western democracies *(such as the* ***US*** *and the* ***UK****)* to become amongst the world's richest and most powerful nations. As a result most 'developed countries' have advanced armed forces whose primary role is to protect the national population. However, when civil liberties are foregone in order to empower the state, *(as in countries such as China and North Korea)* then the state can generate wealth directly from the toil of its people. Government here does not serve its citizens, rather it is the other way around. Indeed, with direct access to a wide range of different resources, some autocratic states *(particularly hard-line socialist ones)* have built 'state-of-the-art' military defence systems to protect their own power with no regard for the welfare of the wider population. Moreover in rigid societies where the fear of dissent has, over several generations, mutated into unquestioned patriotism, a majority of people unwittingly live their lives completely devoted to a system which preserves a strict social strata that only really benefits a privileged and powerful minority.

Ultimately we are all at the mercy of our national homeland, and our very lives depend on its continuing stability. Yet every country is itself dependant on global civilisation. A complete collapse of the Russian, Chinese *(or even **US**)* economies, for example, would no doubt bring irreconcilable social instability. Such an event would inevitably spark international hostilities ~ eventually facilitating the fall of mankind's nuclear *'house of cards'*. Yet the economic fortitude of these three military superpowers does not present the only major risk to the ongoing security of the world's deadliest weapons. Today, there are other nuclear nations in even more precarious social and economic situations. For example, should the totalitarian regime of the ***'Kim'*** dynasty in North Korea feel threatened in any way, it would not hesitate to use its weapons without discretion ~ and with potentially catastrophic consequences. There is also considerable tension in Southern Asia, where social unrest along the border between opposing nuclear powers *(Pakistan and India)* continues to jeopardise peace across the wider region.

Whenever a major regional war threatens to further widen the schism between nuclear powers that are on opposing sides, diplomatic tensions are invariably raised. There is always the sobering possibility that a 'proxy war' could escalate into a direct conflict between countries which are ultimately capable of completely destroying humanity itself. With the **US** and Russia *(along with several other nuclear nations)* reserving the right to carry out a pre-emptive strike on an enemy state in the name of national security, the potential threat of a nuclear attack also adds a horrific dimension to modern psychological warfare. Furthermore, with huge defence budgets fuelling an ongoing arms race to develop fully integrated **AI** weapons systems, the continuing nuclear stability of today's global civilisation has become increasingly unpredictable.

There are, of course, countless possible scenarios that could put a sudden end to the global prosperity and expansion that has dominated human activity over the past number of decades. The Middle East, where religious and political rivalry have inspired the most terrible acts of violence and inhumanity, is perhaps the most likely place to ignite a potential nuclear exchange between opposing forces. An apposite example of this terrifying possibility is the ongoing conflict in Syria. Beginning in 2011, the Syrian Civil War has not only dragged in various different countries and Islamist groups, but its sheer ferocity has helped to erode the moral taboo surrounding the use of **WMD**s. Despite international condemnation, sporadic chemical attacks *(using sarin, chlorine and mustard gas)* have killed thousands of people since 2012. Mostly executed by Syrian government forces under president **'Bashar al-Assad'**, the brazen use of chemical weapons on civilian populations in rebel-held regions of the country was able to continue thanks to adamant denials *(despite overwhelming evidence against the regime)* and, of course, considerable Russian support. These chemical attacks not only threatened to normalise the use of such weapons in warfare, but they incited the **US**, France and the **UK** to carry out air strikes on Syrian targets suspected of being involved in the production and storage of chemical weapons. By definition, the very act of intervention by Western forces against the Syrian regime was inimical to the interests of Russia. Perhaps the greatest danger in Syria remains the possibility that **US**, **NATO** or Israeli forces could come into direct conflict with Russian or Iranian armed forces ~ escalating a war which has the potential to engulf the entire world.

Russia's involvement in the Syrian Civil War and its growing influence in the wider region has caused concern in the West. Its attempt to broker a peace deal along with Iran and Turkey *(but without the involvement of the West)* for example, reinforced suspicions that Russian president **'Vladimir Putin'** was embarking on a crusade to undermine Western values and strengthen his own position on the world stage. Indeed, the remarkable warming in relations between Russia and **NATO** member Turkey *(since it inadvertently shot down a Russian jet on the Syrian border in 2015)* is further testament to this belief. Within two years of this highly charged international incident, Russia had secured a Turkish defence contract for a surface-to-air missile system despite Turkey's obligations to **NATO** ~ including the storage of up to 70 American nuclear warheads ready for quick deployment. Of course, Russia's full-scale invasion of Ukraine has since cooled bilateral relations with Turkey, but constitutional reform here in 2017 increased the risk of a 'democratic backslide' by this strategic **NATO** member.

While forging closer ties with countries such as Turkey, Iran and China, by the late 2010's Russia was becoming increasingly isolated from the West. However, despite suffering a raft of economic and diplomatic sanctions *(for Putin's highly aggressive foreign policies)*, massive investment in modernising its armed forces ensured that, by the start of the new decade, Russia was once again seen as a 'superpower' capable of matching or even surpassing America's military might. Indeed, many believed that, if a major 'incident' occurred which brought the Russian military into direct conflict with Western forces, Putin's confidence was such that he would feel advantaged by conducting pre-emptive strikes on a perceived enemy country.

Although its ill-fated invasion of Ukraine has since laid bare many frailties within the Russian military machine, Putin appears to remain undeterred in his attempt to evoke a personal vision of Russia. As such, he could readily undermine Western power in any number of ways in a bid to change the world order. Indeed, Russian forces could still conceivably attack any number of **NATO** member states, regardless of the obvious repercussions. With calm psychopathic abandon, Putin may still decide, for example, to annex Estonia, Latvia and Lithuania *(spirited by his successful interventions in South Ossetia and Crimea)*. Whilst this would likely incite a severe response from **NATO** that could prove catastrophic for Russia, the likely escalation in hostilities would also seriously threaten world security, and undermine Western dominance ~ ensuring Putin's legacy. An emboldened *(or recoiling)* Russia could even strike out directly at another world power ~ perhaps targeting the United Kingdom *(given recent disputes between the two nations)*. Situated at the edge of a continental mass, Great Britain *(like Japan)* is a 'contained' island nation ~ the ideal target for an aggressor wishing to focus the effective force of any chosen **WMD**.

Direct aggression by Russia on another sovereign nation *(such as the **UK**, France or Germany)* would most likely begin with a concerted cyber attack intended to wipe out the 'national grid' and destroy the country's civil infrastructure. Without power, society would severely falter within a matter of days as general confusion accompanies civil disorder, along with growing hunger and disease. Such a state could continue for several days *(or even weeks)* before complete global instability reaches a 'tipping point' that finally annihilates modern civilisation in an outburst of devastating nuclear exchanges.

Historically speaking, Europe has been a hotbed of conflict and war, and whatever the circumstances of a future nuclear exchange *(and wherever in the world it may begin)*, all European nations would no doubt face obliteration from the continent's inevitable involvement. However, whilst Europe lay at the heart of the previous two world wars, any international conflict of a similar scale would now be virtually inescapable ~ no matter where you lived. Indeed, there is little doubt that a solitary nuclear attack by any nation, anywhere in the world, would escalate into a global war, and every continent on Earth would ultimately suffer beyond comprehension. Even a limited *'Eurocentric'* war between **NATO** allies and Russia *(however unlikely that may be)* would inevitably antagonise other major conflicts centred in places such as the Middle East, Central Africa and Southern Asia.

Of the many possible scenarios that could incite the use of nuclear weapons, not a single one is totally independent of the others. Take, for example, a possible escalation in hostilities between India and Pakistan over Kashmir. Although they have comparatively small developing economies, these two highly populous countries have built sophisticated nuclear defence systems, and are complicit in a dangerous regional arms race. With ongoing border disputes *(which also involve China in parts of north-eastern Kashmir)* and frequent spates of violent unrest, the possibility of sparking a greater conflict is always a possibility here. Indeed, despite India and China maintaining a *'no first use'* policy regarding nuclear weapons, major events elsewhere in the world could easily overtake their commitment to cautious restraint.

When Pakistan became the first Muslim country to join the so-called *'nuclear club'*, a number of other Islamic nations redoubled efforts to realise their own nuclear ambitions. The emergent nuclear programmes of several countries *(including Libya, Syria and Iran)* benefited from the experience of Pakistani nuclear scientists for a number of years and, for the first time since its creation, the modern state of Israel perceived a coherent risk of annihilation from its 'historic enemies'. Indeed it is still not inconceivable that another Middle East country could secretly develop a nuclear warhead capable of being mounted on a short or medium-range missile and fire it at Israel. Should Iran, for example, decide to directly attack Israel with any type of **WMD** *(be it nuclear or otherwise)*, there is little doubt that both Israel and the United States would immediately retaliate. It is more likely however, that Israel would carry out a pre-emptive strike on Iran if it felt that such an attack was imminent. This pivotal moment would likely determine how both the **US** and Russia react to such a turn of events. However, should international hostilities ever reach such a stage, the loss of more human life would be completely overlooked as the two nuclear superpowers exchange blows ~ initially on a European battlefield that draws in France and the **UK** *(despite the inevitable consequences)*. With the other nuclear powers consumed with mutual destruction, China would naturally seize the opportunity to establish control over any Western interests throughout Asia before an unavoidable third world war heralds the end of modern civilisation.

With approximately 260 active warheads in its nuclear arsenal *(a similar number to both France and Britain)*, the People's Republic of China has adopted a 'minimal deterrence' policy. Through 'Western eyes' however, China's somewhat refrained nuclear strategy belies its military posturing over recent decades ~ and this, the world's most populous country, is central to a number of potentially calamitous nuclear scenarios.

Having annexed Tibet in the 1950's, for example, China's ongoing territorial disputes with its small Himalayan neighbour, Bhutan, have turned increasingly aggressive and threaten to entangle it in a dangerous stand-off with India. This is not the only potential military flashpoint. Whilst the historic contention of China's border with Russia has lessened considerably since the late 1960's, its growing military presence in the South China Sea has not. With trillions of dollars of global trade passing through the South China Sea every year, *(not to mention its valuable fishing rights and untapped reserves of oil and gas)*, China has embarked on a policy of fortifying disputed islands and reefs in areas of the sea contested by several other states ~ including Indonesia, Malaysia, Vietnam and, of course, Taiwan. Yet military reclamation projects on a number of reefs *(which include building runways and installing various missile systems)* have allowed China to significantly strengthen its sphere of influence in the region ~ a policy which has led to similar disputes with Japan and South Korea in the East China Sea. As a result, the passage of foreign vessels exercising their maritime rights close to these disputed islands *(particularly **NATO** warships)* continues to keep tensions high.

Despite China's 'offensive military posture' in the South and East China Seas, it would take a serious error of judgement to turn these disputes into an irreversible international conflict. Indeed both China and the United States clearly realise that they have nothing to gain from a direct military confrontation with one another. Even America's overt pressure on North Korea regarding its nuclear weapons programme is unlikely to spur China into a war with the West unless its own territory is directly affected during a potential nuclear exchange between the **US** and North Korea. Moreover, China would only attack Western interests if it perceives intolerable interference in its own internal affairs. In fact *(in similar fashion to North Korea)* China is only likely to embark on a nuclear offensive if its ruling Communist party was under serious threat of losing control of this vast nation ~ perhaps with social instability arising from an inspired pro-democracy movement originating in Hong Kong or neighbouring Burma.

Ultimately, any number of different possible events could trigger a future nuclear conflict. It could arise, for example, from something wholly preventable such as a series of military exercises in a politically sensitive region ~ a major cause of international 'oversight' and 'misread intentions'. Often seen as highly provocative by opposing countries, large-scale military exercises are regularly carried out by **NATO** and Russian forces in Eastern Europe, and by **US** and Chinese forces in South East Asia.

The first use of nuclear weapons in anger since 1945 may even come about by something completely inauspicious and unforeseen. The flailing leader of a 'maverick' nuclear state, for example, could potentially strike a perceived enemy in a desperate attempt to deflect attention from their own faltering power base. All military dictators are capable of such profound individual selfishness *(the act of sacrificing their entire country to preserve their own life)* and those with power to launch a nuclear warhead in anger represent mankind's weakest link between knowledge and wisdom. Yet it might not even be a state player that ignites the fuse of human self-destruction. Another plausible route to future nuclear Armageddon could arise from religious militancy ~ with increasingly sophisticated weapons available, for example, to Islamic organisations that regard it as their religious duty to 'liberate occupied territories' by any means necessary. Open to a variety of interpretations, the ***'Mecca Declaration'*** of 1981, in particular, has provided a growing number of extremist groups with the reason to continue a violent jihad against the state of Israel.

Not all scenarios that have the potential to initiate nuclear Armageddon are even military in nature. It is not inconceivable, for example, that economic factors could one day facilitate an irrepressible wave of civil disorder and violence that spreads across the world. Another 'doomsday scenario' centres upon the weakening *(and possible collapse)* of Asian economies which could bring crippling unemployment to economic powerhouses such as Japan and Hong Kong. It is highly likely that the **US** would intervene in such an event, probably by buying billions of Yen *(primarily through fear of being flooded by cheap imported goods)*. Were such a policy to fail it could potentially bring the **US** economy down with it ~ and if the American economy fails, modern 'Western' civilisation would inevitably collapse. All modern societies around the world *(regardless of nationality)* would likely succumb to the death of today's global civilisation as they slide towards complete anarchy. Under such circumstances, the use of **WMD**s on unsuspecting populations would become far more likely.

Our species is on a path to self-inflicted annihilation and, however it may play out, the result will ultimately be the same. A nuclear war will inevitably mark the end of modern civilisation, and any survivors will be faced with both a dead world and a sickening loss of hope. However the architects of our destruction will continue to inflict further waves of death upon what remains of the human population. Indeed in the initial aftermath of a nuclear attack, the expandability of human life *(and that of all extant species)*, would rise significantly in the minds of warring nations, and any functioning military forces capable of carrying out further strikes would likely do so without caution.

Having obliterated over 95% of the world population in the initial wave of a nuclear war, surviving military authorities *(that had the will to do so)* would have little hesitation in backing up their strikes with further attacks using biochemical weapons. With offensive chemical and biological agents widespread and comparatively easy to produce, any post-nuclear war world is likely to be largely non-survivable for human beings beyond a few decades at most. Ultimately a 'sudden anthropogenic extinction event' in the form of a global nuclear war would likely bring about the death and rebirth of almost all advanced species of life on Earth ~ effectively forcing our living planet to revert back to its own genesis.

Whilst the aforementioned 'end-time' scenarios are speculative, and individually unlikely, they are all nonetheless logically possible. Today we stand at a precarious crossroads not just for human progress and modern civilisation, but also for the very survival of countless other living species. We may be responsible for the extinction of thousands of different animals and plants, and our activities may have irrevocably damaged the health of our living planet ~ but our own species will continue to survive so long as those with the power to detonate a nuclear bomb in anger maintain a sober and reasoned perception of world affairs.

viii.
(Psychological breakdown)

Catastrophic natural disasters have the potential to kill many millions of people at a stroke and most cannot be averted. We could not prevent a large asteroid strike or a 'supervolcanic' eruption, for example, and both could easily wipe out the human population in an instant. In fact there are numerous natural hazards over which we have absolutely no control, yet which have the potential to cause a major extinction event. But the chances of such disasters striking without forewarning are so small that there is no point in being constantly fearful of them, and they are of little concern to us in our day-to-day lives. However, in terms of our species' continued survival, the biggest thing we have to fear is ourselves. Whilst human *'greed'* has degraded our planet's natural resources and severely damaged the delicate ecosystems on which we all depend, the equally powerful emotion of *'hate'* has provided us with a continuous history of warfare, and has driven us to create the most destructive weapons possible. Alas, as a species, we appear to be addicted to both money and conflict, and while our pursuit of wealth is ignorant at best, our inability to establish world peace is shameful. Often wrapped up in righteous idealism, our 'hateful' desire to win wars *(at almost any cost)* is a genetic flaw in the human psyche that could ultimately end up killing us all.

The number of casualties incurred during a war relate directly to its range and intensity. Ultimately however, when conviction can be taken to no greater height, it is the size and extent of the warring populations that will reflect the historic devastation of any given conflict. Indeed the deadliest wars are capable of depleting national populations by millions. Yet during *'total war'* the ratio of casualties to the population size is relatively constant and, throughout history, major conflicts *(like famine and plague)* have sporadically kept population growth in check. But since the second half of the 20th century the world population *(initially in 'developed', and later in 'developing' countries)* has increased tremendously, and the global population today is in excess of 8 billion people. Whilst the Second World War remains the deadliest conflict in human history *(killing up to 85 million people)*, the post-war period has seen incredible technological advances which have improved living conditions around the world, with human longevity increasing markedly over the following decades ~ particularly in the world's wealthiest countries. However modern technology has not just brought social improvements that help us live longer *(such as better medicines, and higher quality health care)* but it has also given us weapons capable of wreaking almost unimaginable horrors. Indeed since the end of World War **II**, the risk of another decisive global war consuming the modern world has been kept at bay by the threat of nuclear annihilation. In fact the very existence of all types of 'weapons of mass destruction' *(be they nuclear, chemical or biological weapons)* has no doubt deterred 'would-be aggressors' from waging all out war directly on a world power or its closest allies. Moreover, the invention of such deadly weapons has incontrovertibly changed the dynamics of modern diplomacy and shaped the ***'United Nations'*** ~ the very organisation upon which we depend to uphold international law and maintain a sense of global peace. Indeed, all five countries that have a permanent seat on the ***'UN Security Council'*** retain strong nuclear deterrents.

Whilst today's civilisation largely benefits the world's wealthiest nations, it engages the lives of billions of people. Yet modern civilisation is very fragile, and its survival depends heavily on the continuance of the current 'world order'. We live in a global community dominated by a Western mindset which not only pertains to cherish human life and individual rights, but which advocates the idea that we are all equal ~ regardless of nationality, culture or religion. As a result, the idea of using weapons of mass destruction against any unsuspecting population is generally met with a reaction of complete abhorrence. However, in more recent years, cracks have begun to appear in the pillars of this 'Westernised consciousness', with the apparent use of **WMD**s *(particularly chemical weapons)* becoming increasingly common within major regional conflicts that continue to blight the modern world.

With the advent of 'twenty-four hour' news coverage, modern technology has enabled hundreds of millions of people to see for themselves the horrific suffering that befalls civilian populations caught up in today's regional wars. When the aftermath of the most hateful crimes against humanity are broadcast around the world *(such as the use of chemical weapons in Syria for example),* the contagious insanity of war can infiltrate the minds of people thousands of miles away. Not only do such attacks spread hate and anger to distant communities but, in using chemical **WMD**s they break a taboo that has helped consolidate a frail world peace for the past three quarters of a century.

Our exposure to 'round-the-clock' news has enlightened civilian populations within most 'Westernised democracies', and people are generally better informed of world events today than they have ever been. However, with public opinion readily swayed by media bias and the manipulation of factual evidence, the proliferation of modern news reporting makes for an 'edgier' world ~ with violent regional conflicts *(and the war crimes that they incite)* entering our collective consciousness through countless media outlets with differing agendas. As a result, the realisation that certain ongoing conflicts could potentially escalate into a full-blown nuclear war has become altogether more acute in the human psyche.

During the latter half of the 20th century, the secretive nature of Cold War confrontations stifled the freedom of Western news corporations *(particularly in times of extreme tension)* ~ preventing a general awareness of many geopolitical flashpoints which ultimately had the potential to change the course of history. A number of historical incidents would no doubt have led to different outcomes had they been exposed by the voracious global network of live news broadcasting that we now experience. The consequences of 'near-miss events' *(such as those involving nuclear weapons)* would also be vastly different were they to occur today. One example was the break-up of a **US** Air Force **B-52** bomber, over South Carolina in 1961, whilst carrying two '4 megaton hydrogen bombs' *(one of which continued through its arming procedure as it fell from the sky)*. Over 250 times larger than the two atom bombs that destroyed Hiroshima and Nagasaki, its detonation was only prevented by a single low-voltage switch. Considered a major ‘classified incident’, the full story of the downed bomber and its deadly cargo was not widely reported until 2013.

The *‘Cuban missile crisis’* in 1962, presents another example when a dangerous stand-off between American warships and a ‘cornered’ nuclear-armed Soviet submarine almost brought about a terrifying nuclear exchange. This pivotal event during the crisis would not be revealed to the public for another forty years. Perhaps the closest that modern civilisation has come to nuclear annihilation however occurred during the barely reported *‘Able Archer/**RYaN** crisis’* in 1983. A **NATO** command post exercise in Europe which simulated a pre-emptive nuclear strike coincided with a Soviet programme to mobilise its intelligence services in the belief that the West was genuinely preparing to attack. Set against a backdrop of mutual fear and distrust between the two sides, these ill-conceived military exercises led many to believe that nuclear conflict was imminent, whilst most people around the world were completely oblivious to it.

Because we are a thinking species capable of contemplating our own demise, there are of course numerous ‘end-time theories’ ~ many of which are based on absurd eschatological beliefs, and have circulated for centuries. Whether it’s the Christian ***‘Book of Revelations’***, the Hindu completion of ***‘Kali Yuga’***, or Islamic ***‘Signs of the Day of Judgement’***, religion has traditionally been at the heart of how we perceive the ultimate finality. However, whilst religious scriptures have historically managed to strike fear into the masses, today such teachings are generally regarded as being fanciful at best. Indeed the greatest danger comes from the growing empowerment of religious extremists, and their ability to bring about a self-fulfilling prophesy.

However not all wayward doomsday scenarios are religious, and not all are totally implausible. Some of the more outlandish ‘secular’ end-time theories, although extremely unlikely to ever occur, are nevertheless logically possible. The idea of ***‘grey goo’***, for example, envisages the uncontrollable proliferation of self-replicating robots that consume the biosphere ~ eventually destroying all life on Earth. Whilst the creation of grey goo *(intentionally or otherwise)* is based on vague science, the field of molecular nanotechnology is growing rapidly, and the idea cannot be completely discounted. Nor too can the hypothesis that one day intelligent computers will no longer need people, and may instigate the extinction of our species through a process of enforced ***‘transhumanisation’***. The idea of artificial super-intelligence triggering a ***‘technological singularity’*** that renders human civilisation obsolete is a similar hypothesis. Another unlikely *‘global catastrophic risk’* plays on the existential threat of universal instability, and the idea that physicists could accidentally create a micro-singularity inside a particle accelerator; an event which could destabilise our dimension and initiate a ***‘quantum vacuum collapse’***. Although seemingly far-fetched, this hypothesis brings together ideas from *‘string theory’* and *‘quantum gravity’* which, given the rapid advancement in laser technology, is not beyond the realms of possibility in the future.

Yet, if asked about their greatest fears for the future of humanity and life on Earth, few people *(apart from those receptive to wayward conspiracy theories)* would consider the aforementioned hypotheses. Most would cite things such as climate change, overpopulation and nuclear war, as like-minded people naturally tend to collectively share their opinions and concerns. This is because our everyday perceptions are heavily influenced by both our peers and the various forms of news media that saturate our day-to-day lives with information about the world around us. Keeping us updated on everything from local issues to major global events, our daily exposure to what is largely *'bad'* news invokes a desire to discuss our own beliefs and concerns with one another ~ allowing some emotional news stories to profoundly affect the national psyche.

A very powerful force, in many developing countries the news media has replaced state religion as the most influential tool with which to control the masses. Even in the West, it can invoke a sense of unity, particularly when, as individuals, we have to come to terms with collective feelings of grief or other forms of emotional shock. The most potent examples of this include the deaths of American President **'John F. Kennedy'** in 1963, and British royalty **'Diana Princess of Wales'** in 1997 ~ both of which incited displays of public hysteria whist spawning feelings of resentment and blame. Perhaps the most divisive peacetime news story of recent years was the ***'September 11 attacks'*** in 2001, where stark images of the unfolding events *(particularly the final moments of the two World Trade Center towers in New York)* brought about a sudden shift in reality for hundreds of millions of people around the world. For most American citizens, public emotion and sensibility were galvanised into a collective feeling of both sadness and anger that, over the following months and years, would morph into a profound sense of national injustice.

Over the past decades, countless news reports have altered perceptions and swayed public opinion on a whole variety of issues at both national and international level. Whilst a vast majority of 'influential stories' are more subtle than the sudden death of a beloved celebrity or a major terror attack, certain news events can bring about a gradual but definite change in public perception ~ instilling new fears into the mass consciousness. Early 21st century examples include those related to the deterioration in relations between Russia and the West, or the sheer scale of plastic pollution and its environmental consequences. As a society, it is our collective awareness or ignorance of certain global events that ultimately determines how we perceive the world outside of our national borders.

Whilst the potential threat of a nuclear war and our abusive exploitation of nature are ongoing concerns which continue to be reported, numerous 'impact' news stories have played a part over the years in driving the collective fear of different communities around the world. The power of the media was especially prevalent as we approached the 21st century at a time of post-Cold War uncertainty. Indeed throughout much of the 1990's, people were particularly vulnerable to emotive news stories, with 1999 in particular bristling with events that had the potential to spark a global calamity *(which ultimately did not materialise)*. Some of the fears that were circulating in the West during this time stemmed from the following widely reported news stories;

The death of **'King 'Hussein of Jordan'** in February 1999 *(an influential figure in the ongoing Israeli-Palestinian conflict)* threatened to bring greater instability to the Middle East ~ one of the most war-torn places on Earth. When terms set at the ***'Oslo II Peace Accord'*** expired three months later without a final agreement, tensions in the region were raised even further. With no sign of free elections in the occupied territories, many feared that the head of the ***Palestinian National Authority'***, **'Yasser Arafat'**, would unilaterally declare independence ~ an act which could readily heighten military activity in the region and spark a wider conflict. Another socio-political flashpoint mired in deep ethnic tensions was the Kosovo War ~ part of a wider regional conflict that had drawn in a number of former Yugoslav republics. For many Western observers, Serbian aggression in the region was reminiscent of events that started the Great War, and many feared that regional conflict here could catalyse a third world war. Whilst June '99 heralded the end of the Kosovo War, it also marked the 10th anniversary of demonstrations by *(and the subsequent massacre of)* pro-democracy students in 'Tiananmen Square' in Beijing. There was considerable concern in the West that Chinese authorities would crack down heavily on commemorative demonstrations in Hong Kong if they felt that mass dissension could spread to the mainland. This was also a time when the free movement of information over the Internet threatened to undermine authoritarian rule in China. The fear that democratic thinkers could slowly infiltrate the communist hierarchy had the potential to severely destabilise the country ~ with many party officials prepared to sacrifice everything in order to resist the growing tide of Western influence.

1999 also had its fair share of unfounded 'non-news' stories which, nevertheless, had a psychological impact on people around the world. In a year when Christian eschatology reached fever pitch, the activity of numerous doomsday cults and marginalised Christian sects ensured that various end-time theories would reach a wide audience *(particularly in America)*. Of course, the religious connotations of the '6th of June 1999' were not lost on the news media. In August, a solar eclipse which passed through Europe, the Middle East and the Indian subcontinent created general panic in a number of superstitious communities across India, where it was believed to be a portent of doomsday. Ironically, rather than dispelling fears, stories reporting the forthcoming eclipse actually served to increase anxiety in many towns and villages. Then, of course, there was the so-called ***'millennium bug'*** *(or **Y2K** problem)* ~ a formatting glitch which was expected to hit many vital computer systems across the world at the stroke of midnight on December 31st. With over $300 billion spent worldwide to fix any anticipated problems, this too was a non-event that played into a *'doomsday psyche'* which had become prevalent throughout the year. Even the deorbiting of Russia's ***'Mir'*** space station in June generated wild news stories which speculated that its uncontrolled descent could potentially rain tons of debris upon a major Western city and kill thousands of people. In the event, the bulk of Mir burned up in the atmosphere as it fell back to Earth two years later ~ with some fragments crashing fairly innocuously into the South Pacific Ocean.

There were, of course, a number of common fears in the West pertaining to Russia ~ particularly regarding its stability in the years following the collapse of the Soviet Union. As a result of gross economic mismanagement under the first Russian president of the post-Soviet era**, 'Boris Yeltsin'**, state assets were sold off at knockdown prices ~ with former Soviet officials, well-connected entrepreneurs, and organised criminal gangs being the biggest beneficiaries. Yeltsin's failed policy of transforming Russia into a capitalist market economy through a programme of rapid privatisation *(which had been endorsed by the **US** government)* ultimately created a small number of extremely wealthy oligarchs. His attempt to open up the country's market using economic *'shock therapy'* was largely driven by his fear of a resurgence in communist sentiment. Yet, besides creating a handful of powerful billionaires, Yeltsin's policy inadvertently diverted state funds away from many essential services and, with government corruption rife, towards the end of the 1990's the country was facing financial ruin. Not only was Russia having to deal with rising crime and poverty in its urban areas but, with numerous civil and military institutions underfunded and neglected, there were major concerns about its national security. Some rogue elements of the former ***'Soviet Army'***, for example, were even guilty of stealing and selling military hardware ~ including nuclear weapons technology. Meantime, without sufficient funding, ageing Soviet-built maintenance systems at several sensitive military sites were becoming increasingly dilapidated and, by the end of the decade, the fear of another potential Russian nuclear disaster was tangible.

The 1990's had seen wholesale changes to Russia's relationship with the West, both militarily and economically. With the Cold War arms race over, both sides reduced their nuclear stockpiles and began to strengthen economic ties with one another. However the feelings of optimism that ushered in the new post-Cold War era were comparatively short lived, and by the latter half of the decade improved relations between East and West had soured considerably. Frequent energy disputes with several countries *(including Ukraine ~ through which a number of vital gas pipelines pass)* raised serious concerns throughout Europe regarding its growing reliance on Russian natural gas. In addition, the world was watching how demoralised Russian forces were dealing with armed rebellion in Chechnya; a republic in the North Caucasus with historic claims of independence.

The unexpected resignation of Russia's enfeebled President on 31st December 1999, and the ascendance to power of former **KGB** intelligence officer **'Vladimir Putin'** would have a decisive impact on these and many other regional and international disputes. Putin's confrontational policies and expert 'power-play' both at home and abroad soon became evident to the West and, as the new decade progressed, Russia's image as a much weakened state and 'fallen superpower' was gradually eroded. From the beginning, Putin used Russian gas exports to influence political decisions in several countries that were heavily reliant upon them ~ often forcing international deals that favoured Russian interests. It was his strong-arm military tactics in Chechnya, however, which really alerted Western observers to the abrasive new direction Putin was taking his country. A revitalised Russian Army ruthlessly crushed Chechen forces in the second war here within a decade, crippling the resistance movement and firmly re-establishing the Kremlin's authority. In the following years, under Putin, Russia would go on to wrestle control of South Ossetia from Georgia *(in 2008)* and annex Crimea from Ukraine *(in 2014)*. Whilst eroding democratic rights and civil liberties, Putin's programme of massive military investment restored a sense of national pride and dignity amongst many Russians, who now saw their country as once more being a formidable force to be reckoned with on the world stage.

Unfortunately Putin's clear miscalculation in invading Ukraine *(in 2022)* resulted in Russia's military 'overstretch' ~ vastly raising the chances of unconventional weapons being used by his increasingly desperate regime.

While political upheaval in Russia at the turn of the century changed the dynamics of international relations, the new century was also ushered in against a backdrop of growing tension in the Middle East. In 2000 the *'Second Intifada' (a Palestinian uprising against Israel that would last over four years)* led to thousands of casualties in the region, whilst a declaration of war on the United States by Saudi-born jihadist **'Osama bin Laden'** in 1996 would also have terrible consequences. The bombings of two **US** embassies in Africa in 1998 and co-ordinated attacks on the American mainland in 2001 also killed thousands ~ thrusting bin Laden's militant Islamist organisation ***'al-Qaeda'*** into the media spotlight. Equally troubling for many in the West was Iraq's dictatorial regime which, under President **'Saddam Hussein'**, had unknown nuclear, chemical and biological weapons capabilities, and was considered a serious security concern in the **US**. His savage repression of Kurdish peoples in northern Iraq and Shi'ites in the south also led many Western observers to fear the possibility of future attacks on Europe and Israel. In an attempt to justify the invasion of Iraq by Western forces in 2003, **US** intelligence made ungrounded links between Saddam and al-Qaeda as well as inaccurate claims about Iraq's hidden stockpiles of **WMD**s. Alas over the next nine years, the war in Iraq would result in well over half-a-million fatalities.

As the 21st century began, various regional conflicts ensured that the peace and security of many countries outside of the developed world remained extremely fragile. Ironically however, it was underlying paranoia in the West itself that presented one of the greatest threats to the stability of modern civilisation. This Western angst was particularly prevalent in the United States. Indeed the most heavily armed nation in the world was also perhaps the most nervous about the coming of the new millennia.

Today many serious global concerns remain, but the dynamic progression of human civilisation constantly changes the immediate reality of our predicament ~ updating our perception of ongoing world events. Recent years have seen the polarisation of various belief systems around the world *(both religious and secular)* with a significant growth in religious and political extremism. Contrary to the notion that scientific enlightenment disparages religious belief, in some parts of the world the Semitic religions have attracted more worshippers than ever. Meanwhile the inherent undercurrent of nationalist sentiment has swelled considerably in many countries over the past couple of decades, bringing highly emotive *(but invariably damaging)* popularist policies to fruition. All the time, discovery, invention, and technological advancement in numerous fields of science continues to change our lives and endow the modern world with new innovations. All technology, however, can be applied equally for beneficial or destructive purposes, and since the turn of the century our knowledge and understanding in so many fields *(from medicine to warfare)* has advanced dramatically. For example, once untreatable conditions *(including certain cancers and congenital disorders)* can now be cured using *'gene therapy'* ~ procedures that can modify, add or remove specific genes within patients. However, this technology can readily be applied to advancing biological weapons, with *'whole genome sequencing'*, for example, enabling military scientists to target the genetic traits of particular ethnicities. Indeed, two decades after a widely circulated, but questionable, report claiming that Israel was looking to build a weapon which was harmless to Jews but fatal to Arabs, the ability to create genetic bioweapons such as this is certainly not beyond the realms of possibility now.

And what is the likelihood of a worldwide conflict actually breaking out again sometime in the not-too-distant future? Were major world powers to actually engage in a direct total war with one another, the question of continuing to uphold international treaties which prohibit the use of **WMD**s would certainly become a moot point. Indeed the prospect of another 'all-out global war' is so terrifying to consider that we have no choice but to avoid it at all costs. Alas today, the future of life on Earth is ultimately at the mercy of our uniquely human inclination to completely destroy our enemies.

With human wisdom seemingly unable to keep pace with technological progress, what is particularly concerning is the direction that international relations have taken since the turn of the century. Indeed, the 9/11 attacks in 2001 proved to be a pivotal moment in modern human history ~ causing a distinct shift in reality for many millions of people who now saw the world as an even more dangerous place. It directly sparked two devastating **NATO**-led wars *(in Afghanistan and Iraq)* that naturally bred even more anti-American sentiment in the region, and emboldened various extremist groups within the Islamic world. This in turn helped to fuel a rise in Christian fundamentalism in the **US** itself. By the late 2010s the fabric of American society was being severely tested by ultra-conservatism within its borders, whilst perceived external threats had now spread beyond the traditional enemies of Russia and China ~ with Iran and North Korea creating an even broader sense of national concern.

In most open democratic societies, the various communications industries that disseminate daily news stories *(including the digital, broadcasting, and publishing media)* can ultimately offer real insight into the future. If our countries continue along a course where national pride and religious intolerance breed an open mistrust of foreign cultures, then violent international conflicts will blight humanity for as long as our species survives. As a growing number of people become ever more aware about the consequences of a major international war, so civilisation becomes increasingly edgy. Indeed we live an extremely fragile existence and the greatest threat comes from ourselves. Omnicide is not an attractive option for anyone, but as our massive global civilisation increasingly struggles to cope with the demands of an overpopulated world and our negligent exploitation of natural resources, so the notion of instigating *'genocide to benefit the few'* may seem an increasingly appealing option to some. Just as an individual must have self-belief to succeed in life, collectively we must have faith in humanity in order to survive our own misdeeds.

Mankind has been greatly empowered by the *gift* of intelligence. It has allowed us to comprehend the world around us, so we are able to manipulate universal laws for our own use, exploit our planet's natural resources to the full, and build vast civilisations that further nurture our hugely successful species. As individuals however, our ability to comprehend the reality of life with 'rational thought' is greatly influenced by our 'language', 'culture' and 'religion'. Separated into nations, we communicate with one another using a common language ~ the quintessential means with which to express our beliefs and ideas, and so form a collective understanding of the world around us. Indeed, subtle differences can arise in meaning or inference during translation into a foreign language ~ a fact which helps define the national psyche. In childhood, cultural values are impressed heavily upon our developing minds, shaping the way we perceive the world as adults and, of course, religion is at the heart of most cultures.

Unfortunately in many countries, throughout the early 21st century, both religion and politics have become increasingly polarised ~ an ongoing trend that threatens to completely destabilise the global economy, and which could ultimately destroy modern civilisation altogether. Indeed radical religious and political ideas are gradually becoming normalised, marking a gradual shift in the 'cultural mindset' of many countries. For example, religious fanaticism *(whether it be Islamic Wahabism, Christian Identity, or Jewish Zealotry)* has had a profound impact on the perception on reality for millions of people, and has made the world a far more dangerous place. The significant rise in religious fundamentalism over the past few decades threatens to overtake secular rationale, and the belief in an *'afterlife'* makes it more likely that a 'pressured' world leader could risk nuclear war in the misguided notion that their actions are being done as *'God's will'* ~ or even just for the *'better good'*.

Whilst the current leaders of most nuclear-armed nations are either atheist or do not hold overtly radical views concerning their faith, the continuation of secular rationale in the future governance of some of these countries cannot be guaranteed. Indeed, modern society *(particularly that of Western convention)* is built on the historic foundations of religious power, and it is still very difficult to avoid the overtones of religion as a 'righteous legacy' in everything from law and tradition to our very language. Even the word *'atheism'* itself implies that believing in a god is the norm, yet religious belief is not innate. No one is actually born with faith in a particular god ~ it is a learned behaviour.

Today, atheists account for a large but silent minority in the Western World, where most people are either *'agnostic'* or *'part-time believers'* who take comfort in the idea of 'God' but do not apply *(or have no use of)* their faith in daily life. The highest proportion of atheists amongst the general population occurs in East Asia *(which is dominated by either traditional Eastern philosophies or the anti-religious policy of communism)*, and Western Europe *(where the once unwieldy power of Christian authority has been gradually eroded over recent centuries by scientific reason and the liberalisation of society)*. Here a rise in explicit atheism during late 20th century has today created a conscious rejection of traditional religious strictures. 'Common-sense' atheism in Europe continues to grow despite the resurgence of highly emotive Christian denominations throughout much of America.

Fervent believers in a religious faith, generally speaking, are the most dangerous people to hold power. Although moderate religious belief in society is slowly decaying, in some parts of the world *(especially throughout Africa and the Americas)* the two largest Abrahamic religions *(Christianity and Islam)* are being boosted by a growing number of churches and mosques which uphold fundamentalist or extreme interpretations of favoured scriptures. Unquestioned religious belief has the power to deviate the mind from accepted reality, and can direct the social attitude of entire communities ~ breeding a warped sense of morality. In a number of southern **US** states, for example, children are routinely indoctrinated by fanatical Evangelists, most of whom fervently preach their extreme religious ideals in the face of reason. In some rural American communities 'non-believers' are even ostracised from society which, over the past few decades, has seen the *'evil threat'* of communism replaced by a distrust of all things Muslim.

A similar programme of radicalisation is happening in the Islamic world too ~ a process which has bred religious fanatics who are prepared to commit atrocious acts of inhumanity. Since the turn of the century, they have collectively murdered hundreds of thousands of people who did not *'submit to the will of God'* as they interpret it. Whilst Christianity and Islam are both responsible for incalculable misery and suffering around the world, the Jewish community have historically suffered most of all. The oldest of the Abrahamic religions, Judaism is extremely insular ~ a trait which both consolidates the faith and restricts its appeal. As a result however, Judaism is saturated with various ultra-orthodox groups, and as a small nuclear nation in the heart of a predominantly Muslim region, the state of Israel is permanently engaged in a paranoiac war with the outside world, always fearful of anti-Zionism ~ even from within its own borders.

Whilst most Eastern religions perceive life on Earth in terms of *'cyclical regeneration'*, the Semitic faiths adhere to the notion of a final *'day of judgement'* which, in Christianity for example, plays out through *'Armageddon'* ~ an ultimate battle between 'good' and 'evil'. From here, the idea that *'only the faithful who live their lives in accordance with God's wishes can pass into heaven'* adds a dangerous element to purposive human destruction. Indeed, with the concept of *'end times'* firmly ingrained in Jewish, Christian, and Islamic faiths, an illusory sense of existence can easily arise wherein adherents envisage an absolute end to the human physical form but their own metaphysical survival through redemption of the 'soul'. Alas this very notion can readily form the basis to commit genocide and incite 'holy' wars.

There are, of course, numerous variations on religious 'end times,' and a huge array of extremist doctrines predicting the impending fall of mankind. Naturally, conspiracy theories regarding apocalyptic doom are rife, and there are a plethora of different spiritual and pseudo-religious organisations vying for potential disciples around the world. Whilst a number of dangerous cults advocate *(or even attempt to instigate)* an apocalyptic end to civilisation, not all are based entirely in Semitic tradition. The belief system for one such doomsday cult. ***'Aum Shinrikyo'*** *(or Supreme Truth)*, for example, mixes various Eastern religions with stark elements of Christian eschatology to indoctrinate its followers. Known to have had active plans for total human genocide, its founder **'Shoko Asahara'** was executed in 2018 for organising a deadly sarin attack in Tokyo's subway in 1995 which killed 13 people and injured several thousand more. There are even radical secular organisations, such as the ***'The Gaia Liberation Front',*** that champion the idea of a bioengineered Armageddon. Co-ordinated by misanthropic environmental activists, the **GLF** believe the complete eradication of *Homo sapiens* is the only way to ensure the healthy survival of our living planet.

Of course it is not just religious *(and spiritual)* fanaticism that poses an inherent danger to humanity. The first decades of the current century have witnessed an increasingly aggressive stance between the old Cold War adversaries and, with massive investment in military hardware employing **AI** and genetic technologies, entirely new kinds of weaponry have yet to be unleashed in anger.

Historically speaking, new technology has never eased war ~ it has just added to its potency ~ and, in many ways, the most sinister of all modern weapons are those that utilise *'cyberspace technology'*. Indeed, in the ongoing international arms race between various countries, the ability to control the cyberspace of an adversary is regarded as a nonpareil instrument of power. Today there are millions of computer hackers with malign intent, with almost as many state-sponsored malware developers as there are private *'hacktivists'*.

An effective way to subvert an 'enemy state', malicious computer programs can be designed to perform very specific functions. Whether they take the form of *'Trojan horses' 'viruses'*, *'worms'* or *'spyware'*, invasive programs have the ability to wreak havoc in the modern world. In fact, because there are so many different types of malware, the most sophisticated *'cyberweapons'* built by military programmers can be tasked to do almost anything, and many have the capacity to completely paralyse some essential functions of society at the press of a button. An unchallenged cyberattack could, for example, be directed to harm the economy by denying critical Internet access, or it could even cause physical damage to the electronic infrastructure of a targeted state. Moreover, cyberweapons can not only be used to destroy power grids and telecommunications systems, but they could potentially inflict subtle *(but equally damaging)* harm to a nation state in any number of ways. Indeed 'military-grade' malware could silently cripple an array of essential institutions in virtually every aspect of civilian life. Whether it is the banking and finance sectors, air traffic control, food supply chains, schools, hospitals or law enforcement, all modern societies are completely reliant on electronic infrastructure, and therefore ultimately face a significant threat from cyberattacks by malevolent foreign powers or groups that actively promote extreme ideology.

Not only do several major state players *(including the **US**, Russia, and China)* invest heavily in cyberwarfare, but malign cyberspace technology is often used as an avenue of attack for numerous political and religious organisations intent on destabilising the modern, Western-dominated 'world order'. The vulnerability of various national institutions around the world have been greatly exposed in recent decades, with a number of co-ordinated attacks breaching the cybersecurity of various countries.

Primarily used for the purposes of 'espionage', 'sabotage' and 'propaganda', a well-planned cyberattack has the potential to permanently damage the fabric of modern society.

For a vast majority of people, it is difficult to comprehend why anyone would want to willingly incite social chaos and inflict mass suffering in such a way. Yet although, as individuals, we may generally express kindness towards other people, our species as a whole has a sublime inclination towards destruction, domination and the procurement of power. Not only that, but we tend to collectively distrust foreign cultures that are different to our own. As such, *'information warfare'* forms an intrinsic part of our collective desire to attack outside forces that we see as a threat to our own cultural existence. Indeed, the creation of well defined nation states over the past few centuries has only served to focus this strange human inclination to embark on the path of war with one another.

With a number of governments around the world actively seeking to compromise 'adversary states' by hacking their defence systems and stealing classified information, *'cyber-espionage'* continues to grow rapidly. Specially-designed malware can often operate for several years undetected before is eventually discovered *(and named)*. Whenever this has happened, investigations to establish its country of origin, have always resulted in robust official denials from the perpetrating authorities, with accusations often deflected towards private hacking groups.

One of the most notable series of espionage attacks to date was known as ***'Titan Rain'***; part of an *'advanced persistent threat'* perpetrated by China against the **USA**. Eventually exposed in 2003, the origins of Titan Rain were traced to a 'cyber security squad' belonging to the ***'People's Liberation Army'***. This hugely sophisticated operation was China's first significant foray into cyber-espionage, and it successfully managed to steal sensitive information from a large number of **US** interests *(including the **'FBI'**, **'NASA'**, and **'Lockheed Martin'**)*. Discovered in 2004, one particularly effective malicious program from China was assigned the name ***'NetTraveler'*** ~ a highly successful piece of malware which gathered information using a technique known as *'spear-phishing'*. This too was attributed a well organised hacking group with direct links to Chinese authorities, and it infected hundreds of high-profile servers; breaching both corporate and personal security systems around the world. Perhaps the most unremitting spyware to blight the Internet, variations of NetTraveler remained active for at least a further twelve years after its initial discovery.

Of the many malicious programs designed to sabotage foreign interests, perhaps the best known is ***'Stuxnet'*** ~ a computer worm jointly developed in 2005 by **US** and Israeli programmers specifically to sabotage Iran's nuclear programme. Remaining fully active and completely undiscovered for five years, the Stuxnet cyberweapon infected over 200,000 Iranian computers and caused substantial damage to the country's nuclear industry; resulting in the destruction of thousands of centrifuges.

Perhaps the earliest example of one nation using cyberspace technology to sabotage the society of another occurred in 2007, following a highly emotive dispute about a controversial Russian monument in Estonia. It resulted in Russia attacking the small

Baltic state with a number of co-ordinated and 'surgically specific' cyberattacks which would bring temporary paralysis to Estonian society. Against a backdrop of rioting in the capital Tallinn *(which would spread around the country, over the following days)*, Russian hackers carried out several *'distributed denial-of-service'* attacks, using *'botnets'* to inundate Estonia's electronic infrastructure. It managed to take out the electrical power grid as well as various telecommunications media *(including its main broadcasting agencies)*. It even disrupted the Estonian parliament, prompting ***'NATO'*** to step up cyber-defences within the country. Using nothing but 'information technology', Russia's covert cyberattacks ultimately hit the Estonian economy very hard and caused considerable suffering.

By the end of the decade, a number of sovereign states operated worldwide cyber-espionage networks, though all would naturally deny their existence. Discovered in 2009, China's highly advanced ***'GhostNet'*** operation primarily targeted foreign ministries and agencies, and played a significant role in the country's furtive efforts to sustain an 'advanced persistent threat' against Western interests. One piece of malicious code in its arsenal was a Trojan horse *(subsequently named **'Gh0st RAT'**)* which could penetrate a host server and take 'real-time' control of computers on the network, allowing Chinese hackers to utilise video and audio security systems to their own advantage. One of the most complex cyberweapons to be unleashed at this time was ***'Flame'*** *(a.k.a. **'SkyWiper'**)*, a highly sophisticated piece of intelligence-gathering malware which was eventually exposed in 2012. Primarily targeting various organisations in the Middle East, Flame infected a wide range of computers that ran on ***'Microsoft Windows'*** operating systems, and was jointly developed by the *'NSA'* in America and *'GCHQ'* in Britain. Discovered in the same year, the Russian spyware ***'Red October'*** also exploited vulnerabilities in Windows-based programs; infecting thousands of computers *(situated everywhere from nuclear power installations to government agencies)*, and successfully garnered a considerable amount of sensitive diplomatic information before being shut down the following year.

As the decade progressed co-ordinated cyberattacks against the national interests of various countries would become increasingly sophisticated. Russia, in particular, had an active programme of interference in foreign internal affairs around the world, and it used cyberspace technology extensively in a concerted effort to advance its interests abroad. One of the most severe state-sponsored cyberattacks on a foreign country were those committed by Russia following the collapse of Ukraine's pro-Russian government in 2014. In an attempt to abate the growing pro-**EU** sentiment throughout much of the country, Russia embarked on an intensive programme of sabotage and propaganda that manifest as a series of cyberattacks. These sought to both weaken Ukrainian armed forces and incite further civil unrest. Perpetrated by notorious hacking groups which have a direct association with Russian military intelligence *(including **'Sandworm'** and **'APT28'** [a.k.a. **'Fancy Bear'**]),* Ukraine was totally unprepared to deal with an 'advanced persistent threat' from its larger neighbour to the east. Using a number of malicious programs *(which included **'X-Agent'** and **'Turla'** [a.k.a. **'Ouroboros'**]),* Russia successfully managed to bring chaos to the country. It caused a complete power grid outage across Ukraine for several hours, and brought significant disruption to the nation's rail network. It also disrupted the 2014 Ukrainian Presidential elections with sustained 'denial-of-service' attacks, and even distributed infected *'apps'* that effectively destroyed or damaged an appreciable amount of Ukraine's military hardware.

Russia's use of cyberspace technology to create instability in other sovereign nations goes much further than concerted network attacks on border countries such as Ukraine, Estonia, and Georgia. Indeed, in 2016, state-sponsored Russian hackers sought to influence the outcome of both the American Presidential election and an **EU** referendum in the United Kingdom. Their campaign of stealthy interference included activities such as hacking the e-mails of key figures and releasing sensitive data, as well as maintaining a hidden *(but assertive)* presence on social media in order to spread disinformation and propaganda. In the end, Russia's attempt to influence public opinion on highly emotive issues in the **US** and the **UK** was enough to bring about desired outcomes ~ with the results ultimately serving to weaken the position of both America and Europe. Moreover, Russia continues to subvert the democratic process in a number of countries and, as rising nationalism and populism fragments the 'West', the hard-line authorities of both Russia and China have become increasingly empowered on the world stage.

In 2017, two major cyberattacks caused serious economic disruption around the world, and both employed *'exploit'* software, developed in America, known as ***'EternalBlue'***. The first of these involved a North Korean *'cryptoworm'* named ***'WannaCry'*** which masqueraded as privately-created ransomware. WannaCry attacks infected millions of computers worldwide, and temporarily debilitated vulnerable institutions including hospitals, universities, and law enforcement agencies, as well as various multinational corporations that play a critical role in the present globalised 'Western economy'. The many high-profile victims of this cyberattack included the **UK**'s ***'National Health Service'***, and a number of Indian state governments, as well as companies such as ***'Boeing*** in the **US,** ***'Honda'*** in Japan, and ***'Telefónica'*** in Spain. A second major cyberattack a month later, would become the most destructive to date ~ causing billions of dollars in damage and jeopardising millions of lives around the world. Using a Russian *'wiper'* malware named ***'NotPetya'***, the attack initially struck Ukrainian interests such as banks, media outlets and metro systems before spreading rapidly across Europe, with subsequent damage reported in Australia and the **US**, At its height, NotPetya even caused radiation monitoring at the ill-fated Chernobyl power plant to briefly go off-line.

We live at a time when 'information warfare' is perversely essential to maintaining peacetime security and, with civilisation increasingly reliant on cyberspace, computers are becoming weapons in their own right. Indeed today computer scientists and radio frequency engineers are at the forefront of modern military progress, as rapid advances in electronic weapons technology have created a new *(and extremely dangerous)* digital arms race. Cyberweapons represent the ultimate application of military science to urban conflict, and a growing number of countries are regularly engaged in concealed cyberattacks against one another ~ effectively conducting a virtual war that has the potential to break out into the physical world with devastating impact. With *'cyberweaponry'* constantly being upgraded, we risk opening the ultimate *'Pandora's box'*

When taken to its logical conclusion, the violation of cyberspace for military gain will undoubtedly have terrible consequences for humanity. Should, for example, the national cyber-security of a major world power be completely entrusted to artificial intelligence *(i.e. a system that is free to make proactive decisions without any human involvement),* then modern civilisation would inevitably risk an uncontrollable global conflict of its own making. Unlike the ***'Terminator'*** films, however, it will not be the machines who consciously choose to rebel and destroy humanity, rather it would likely come about as a direct extension of human wrath ~ in the form of an offensive **AI** program designed by people *(possibly Russian or Chinese programmers).* Were this to happen as part of an 'advanced persistent threat' against the West, an **AI** cyberweapon could closely monitor pertinent world events so as to take advantage of any vulnerability in Western defences. This would enable it to precisely co-ordinate targeted strikes in the wake of any developments that have the potential to expose further weaknesses. The ultimate game-plan would be to continue until such point that it knows **NATO** would be unable to fully respond to a catastrophic *'full-spectrum cyberattack'*. Indeed, why hold back if it was almost certain that damage from any reciprocal attack would be inconsequential?

Even without relinquishing full control of cyberspace to **AI** technology, it is now possible to wreak incalculable destruction on a perceived *'enemy state'* without even declaring war. In an age where electronic viruses can be used to manipulate information, undermine society, and effect the lives of billions, our continued existence has become dependant on the whimsical decisions of a few powerful men for whom these silent war games represent a struggle for dominance. The sickening reality is that cyberwarfare breaks down the once well-defined boundaries between civilian and soldier and, in an all-out cyberwar, everyone and everything would become a legitimate target.

Throughout history both religion and politics have been extensively used to justify war because, without deadly conflict, there can be no consolidation of power. It is through war that mankind has evolved the notion of national identity and it has led directly to the formation of different countries. Indeed, in a world without the 'persuasive' element of military force, 'international' disputes would amount to little more than negotiation and litigation. Ultimately, however even the severest of trade embargoes and diplomatic sanctions cannot force the will of one sovereign state upon another. It seems, only too often, that the declaration of war *(often by political or religious leaders who will not engage directly in the fighting themselves)* is used to settle 'moral disagreements' between discordant 'enemy powers'.

By the start of the current century, the combined arms budget of the world's nations had topped **$**1 trillion annually ~ with military funding in the **US** accounting for approximately half of all global investment. Furthermore, the historic undercurrent of mutual distrust that exists between various countries has led a number of sovereign states to build huge armies, with some retaining mankind's most potent weapons in the name of national security and civil defence.

Amid growing tensions around the world, the **US** military still maintains the 'right to strike' without precondition, and actively supports the continued expansion of the ***'North Atlantic Treaty Organisation'.*** Since the end of the Cold War, membership and affiliation of **NATO** has grown considerably, not just throughout Europe, but globally. The addition of former ***'Warsaw Pact'*** countries and Soviet Republics *(such as Romania and the Baltic states)* as well as new 'global partners' *(including Japan and South Korea)* have further strengthened the organisation. Indeed **NATO** is even perceived to be encircling 'old foes' Russia and China who both retain a desire to expand their own influences abroad *(notably in Eastern Europe and the South China Sea respectively)*. Russia's active policy of inciting unrest in Ukraine and Georgia *(which aspired to join **NATO**)* and the assertive territorial claims over numerous small islands and reefs by China put considerable stress on some international relations. Essentially, the **US**, Russia and China have all been guilty of positioning missile bases in regions of strategic importance ~ often under the pretence of targeting 'rogue states' or 'terrorist organisations'.

Given its enormous funding and access to the world's most advanced technologies, the **US** ***'Department of Defense'*** believes that the United States can ultimately win any conflict, anywhere in the world. Billions of dollars are spent every year to ensure that it has the ability to 'out-muscle' hostile forces *(should it need to do so)* on land, at sea, in the air or, indeed, in space. Called *'full-spectrum dominance'*, this position of superiority is supported by an extensive range of different weaponry and military hardware. For example, the **US** military possesses almost 10,000 aerial drones *(or UAVs)* and over half of the world's 25 aircraft carriers, whilst leading the world in everything from advanced satellite systems to genetic research facilities. In this age of digital information it not only dominates the physical realm, but operates an extensive programme of research and development into *'network-centric warfare'* in the virtual domain of cyberspace.

In some fields of advanced military research the United States is certainly not alone. Yet whilst Russia and China, for example, have well-developed cyberwarfare programmes that employ various **AI** technologies *(including 'deep learning' architectures)*, the **US** arms budget is so large its vast resources can be applied to any conceivable field of preparatory military research. Indeed in America, research and development into the technologies of war is equally focused in a number of different directions ~ ranging from the smallest possible scale to largest imaginable. Nanotechnology and the military appropriation of micro-machines has not only given American Generals another option of potential attack, but it has enabled military scientists to work on the further development of nuclear weapons without the concern of breaking the international test ban treaty. Whilst the adaptation of micro-technology to simulate nuclear explosions is a novel development, another field of research by the **US** military has the potential to completely change the dynamics of modern warfare.

Recent decades have seen rapid advance in the development of *'directed-energy weapons'*; such as high-velocity ***'railguns'*** that use electromagnetic force, as well as ***'sonic***,' ***'plasma***,' and even ***'particle-beam'*** weapons. The most widely researched type of directed-energy weapons however employ laser technology, and include

'electro-lasers', 'x-ray lasers', and ***'microwave lasers'*** *(or 'masers')*. Whilst many programmes to build efficient laser weapons systems have historically been short-lived, research by the world's largest military powers has intensified significantly over recent years as advances in artificial intelligence have increased their efficiency and practicality. Indeed, **AI** technology has been successfully applied to everything from reducing overall running costs, to overcoming practical issues ~ such as improving the spatial coherence of laser beams and preventing 'thermal distortion'.

Despite the 1967 ***'Outer Space Treaty'***, the feasibility of a large military power successfully deploying a working space-based weapon system is greater today than it has ever been. Indeed, technology has vastly improved since the days of America's controversial ***'Strategic Defense Initiative'*** *('SDI' or 'Star Wars' programme)* which was first announced by **US** president **'Ronald Reagan'** in 1983. The initial concept of **SDI** was to protect the United States from a nuclear attack using a network of both ground and space-based anti-missile systems. Much of the early focus was on developing space-based interceptors including nuclear powered x-ray lasers, and chemical lasers. Restricted by the practicalities of late 20th century laser technology and seen as little more than a profligate ambition after the end of the Cold War, by 1994 the **SDI** organisation was eventually dissolved. However, the continuation of intensive research by the **US** and other major military powers has gradually turned science fiction into science fact, with technological advance enabling us to manipulate, with greater dexterity, the laws of physics for the purpose of warfare.

Within the world's largest military arsenals are hidden hugely powerful, yet unconventional new weapons systems that have yet to be used in anger; including an array of *'directed-energy'* and *'hypersonic weapons'*. Further more, so long as our present model of global civilisation is sustained, the militarisation of space is inevitable. Space is indeed the 'final frontier' for any full-scale future war that may involve any *(or all)* of the major world powers. As has historically happened on land, at sea and in the air, space will invariably provide a battleground for the wrath of mankind against itself. Indeed a number of space-based lasers and railguns *(deployed by the **US**, Russia and China)* are already operational despite stringent 'arms control' agreements forbidding their development.

Whether it be autonomous drones, genetic bombs, tactical **EMP** devices, or space-based lasers, an essential part of developing new weapons systems is simulating their use and *(where possible)* field testing. Once they have passed initial trials, the most promising experimental weapons systems are invariably incorporated into military exercises, where their use is implicated in the simulation of various wartime scenarios. Expensive military manoeuvres form a regular feature of America's national defence policy, and are regularly co-ordinated with its international allies. Indeed the **US** armed forces hold daily exercises *(both independently and as part of **NATO**)* ~ with new military technologies often tested in full-scale simulations without serious casualty. In reality however, the mere threat of introducing an unconventional new weapon systems to a future battlefield is a hugely dangerous development which risks destabilising the precarious peace that binds global civilisation and enfranchises the current world order.

Nevertheless the application of scientific discovery to new military technologies is not only the mother of invention, but a catalyst to human endeavour *(which further advances many fields of modern science)*. It is a sad fact of life that the **US**, Russia, China, and indeed all of the world's major military powers, are guilty of secretly researching and developing controversial new weapons systems which could be deemed to violate 'international law' by an enemy state. By the mid-2010's years of growing mutual distrust had seriously fractured the economic and diplomatic relationships between America and its greatest military rivals; namely the increasingly assertive Russia and the rising economic powerhouse of Communist China. It has resulted in these nations continuing to research and develop new, high-tech military hardware, much of which is highly secretive and unknown to the general public.

When pressed, most **US** citizens admit to feeling comforted by the fact that their country is perceived to be the world's dominant military power. Yet in reality very few people would actually survive a modern war that required America to use its full force. Indeed, whilst many patriotic Americans feel empowered their nation's military might, a vast majority of civilians would feel totally sickened if they could personally witness these deadly weapons in action, and would be completely petrified if they were to come under attack from foreign forces using similar weapons. Most people simply could not comprehend the horror that many new weapons systems can wreak, and are content to passively support continued military research in the name of 'national security' and 'civil defence'. Indeed when new weapons are unveiled, they are often viewed with awe and fascination ~ reinforcing the concept of national pride. Whenever powerful military hardware *(such as an advanced fighter jet or missile system for example)* is deployed to defend one's country or its national interests, it is human nature to feel collectively empowered, and people readily tend to perceive the 'beauty' of a weapon rather than dwelling on the appalling devastation that it can bring.

Yet military technology is always advancing, and remains far beyond public perception at the time. In order to avoid being made obsolete by the advances of foreign military powers, the armed forces of many nations are continually being updated ~ with the greatest world powers always anticipating a 'revolution in military affairs'. Indeed many thousands of military scientists in the **US**, Russia, and China are actively conducting assiduous research into revolutionary technology and the value of entirely new kinds of precision warfare.

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Europe has been the battleground for some of the bloodiest conflicts in human history. It has witnessed literally hundreds of major wars, and played host to many thousands of deadly battles over the centuries. In fact, the total number of casualties from European conflicts runs into hundreds of millions of people; stretching from the 400 year-long ***'Roman-Etruscan Wars'*** *(circa 753-351* ***BCE****)* which were instrumental in the rise of ancient Rome, to the ***'Yugoslav Wars'*** *(1991-2001)* which saw the most recent acts of genocide on European soil. Moreover, the European theatre of war lay at the heart of the 20th century's two most devastating global conflicts; the ***'Great War'*** *(1914-18)* and the ***'Second World War'*** *(1939-45)* which together resulted in over 80 million deaths worldwide. Indeed many of the most destructive wars in history were Eurocentric. These included the ***'Thirty Years War'*** *(from 1618-48 ~ when widespread violence, famine and disease collectively killed over 8 million people)*, the ***'Napoleonic Wars'*** *(which, between 1803-15, ultimately contained the* ***'First French Empire'*** *at the cost of almost 4 million lives)*, and the ***'Russian Civil War'*** *(a catastrophic political war from 1917-22, that resulted in up to 12 million [mostly civilian] casualties).*

Over the years, a succession of wars between various European powers have served to reinforce national pride, and historic battles have played a significant role in defining national identity. Indeed, despite the horrors of war and the carnage that invariably ensues during battle, nationalist sentiment has an unhealthy tendency to celebrate and romanticise victories of the past. However, the reality of war for both the soldiers and civilians caught up in it, is starkly different from that which is often portrayed years later. Yet its negative impact on the human psyche is unquestionable.

From the *'Battle of Agincourt'* in 1415 to the *'Battle of Berlin'* in 1945, the psychological impact of war can be devastating for survivors from all sides. The first of these was a decisive battle in which English longbow men slaughtered thousands of French swordsmen during the drawn out dynastic ***'Hundred Years War'*** *(1337-1453) [in which France eventually triumphed at a huge cost to both nations]*. The latter was the last major offensive in Europe towards the end of the Second World War, when the Red Army comprehensively overran the German capital ~ taking bloody revenge on anyone who had anything remotely to do with the Nazi regime. Despite being five centuries apart, the sickening and oppressive mentality of extreme human violence felt by those involved in either battle would have been strikingly similar.

The most recent deadly national conflicts on European soil have occurred between Russia and various former Soviet states that have since aspired to Western ideals and striven for closer ties with organisations such as **NATO** and the **EU**. Whilst the political map of Europe has changed dramatically since the collapse of the Soviet Union in 1991, the re-emergence of *'Cold War'* military rivalries between East and West in recent years have coincided with violent attempts to undermine open democratic values in places such as Ukraine and Georgia. A direct result of Russian irredentism, the ***'War in Donbas'*** *(2014-22)*, for example, claimed the lives of over 11,000 people and provided useful provocation for a large scale invasion of Ukraine that would kill many, many more.

Whilst the war in Donbas was largely limited to violent regional skirmishes between Ukrainian forces and pro-Russian insurgents for almost a decade, it provided the backdrop for numerous atrocities *(including the mass murder of 298 people on a commercial flight between Amsterdam and Kuala Lumpur, which was recklessly shot down by anti-government rebels in 2014)*. Indeed, despite widespread international condemnation of this and other instances of state terrorism by Russia over the following years, '**Vladimir Putin**'s dangerous ideological ambitions went largely unchallenged by the West. This enabled him to continue inciting unrest in border states where the plight of ethnic Russians was used as a pretext for direct military involvement. Alas, like all deadly regional conflicts, Russian-backed insurgency in Donbas had the potential to escalate into a much wider war ~ and so it proved.

Unfortunately, the catastrophic *(and completely unavoidable)* Russo-Ukranian war that unfolded in 2022 was ultimately caused by one man's romanticised vision of his country's military resurgence and its unequivocal position on the world stage. Apart from the direct involvement of the world's largest nuclear power, this war in Europe, however, is no different to any other, and it can ultimately only end with some form of diplomacy. Indeed, until diplomatic solutions are found, most serious conflicts become increasingly vicious as they progress. War has a tendency to disparage rational thought, and by exposing people to extreme stress through hateful *(and often horrific)* encounters, it can upset emotional stability and readily degenerate the mind. In a prolonged, intensive war, ethical standards are invariably compromised by a desire to win at all costs. Aggressors are more liable to lose sight of the collective human rationale, and can genuinely *believe* that they are morally righteous in their actions; no matter how depraved they may appear to the outside world.

A vast majority of people whose lives have been overtaken by a major deadly conflict are unwilling participants, and their main focus is on survival. The immediate concern for most civilians caught up in war, is their own safety and usually that of endangered family members. Even most *(non-radicalised)* combatants who are in the front line of a deadly conflict are fearful for their own lives, and ultimately value their survival *(and that of their comrades)* above any long-term military objective that they are ultimately fighting to achieve. However, particularly during prolonged and bitter wars, notions of self-preservation are gradually eroded *(along with rational behaviour and a sense of morality)*, as the price of victory loses all meaning.

Whatever 'righteous claims' a warring state or organisation may have used to support its reason for embarking on a war *(whether it be founded in political ideology or for a religious cause),* almost everyone directly engaged in the ensuing hostilities will invariably suffer some sort of psychological discord as a result of their experiences. This will often include the loss of a beholden sense of morality, with the all-consuming notion of *'winning at all costs'* reducing any previously perceived value on human life. Alas our humanity is readily lost to the irrational violence of war, and the sickening depravity typically found in war zones through the years is testament to that fact. The most grotesque war crimes however are usually committed by those intent on either wiping out an 'enemy' population *('genocide')* or completely displacing it *('ethnic cleansing')*. Indeed there are countless examples of armies using inhumane aggression in order to achieve their deadly wartime objectives. The genocidal intent of Nazi Germany, for instance, gave rise to thousands of extermination camps and labour camps across central Europe during the 1930's and early 40's ~ bringing an agonising death to many millions of prisoners. Despite a stark post-war recognition of Nazi atrocities, the use of mass execution and internment was again repeated over 50 years later by Bosnian-Serb armed forces; who built concentration camps to enforce their own policy of ethnic cleansing. This blind disregard for the life and the dignity of all anyone regarded as the enemy *(irrespective of age and gender)* was also evident in the ***'Kosovo War'*** when atrocious acts of perfidy included Yugoslav fighter jets masquerading as 'friendly' **NATO** planes in order to attack fleeing refugees.

The scale of death and destruction that human conflict can bring to an unsuspecting population is horrifying and, for many people, it is simply unimaginable. Indeed, unless someone has personally suffered the appalling carnage of war for themselves, it is almost impossible to imagine just how much wartime experiences can alter an individual's perception of life. The European battlefields of both world wars, for example, will have forever been ingrained in the minds of survivors. Only they could recall the sensation of war as it left its impression on their senses. The overwhelming stench of death and disease, of open sewers in the towns, and of the rotting carcasses of dead cattle in surrounding fields. The sight of extricated limbs and organs, and the contorted bodies of the dead and dying strewn about bloodied landscapes. The sound of people suffering unimaginable horrors, sporadically being drowned out by the noise of ground-shaking explosions coming from all around. Often hungry and cold, many desperate survivors would have been surrounded daily with the unbearable cries and screams of the injured, the grieving, and those whose insanity had found them.

In such an utterly depraved environment, the chances of survival for anyone directly involved in armed combat will depend heavily on strategy, good fortune and teamwork. The lives of combatants fighting on the front line during the two world wars were bound by the necessity of mutual trust, with only discipline holding together companies and platoons of emotionally fractured soldiers. Indeed the most efficient fighting forces are those without emotion, and the military tenet of strict order and discipline serves to focus the minds of soldiers during battle ~ which in turn strengthens the collective desire to inflict defeat upon an enemy. However, whilst making war more bearable, military indoctrination can also perturb emotional balance, and for many faced with the harsh realities of war, it can induce a cold *'black and white'* perception of life ~ allowing some soldiers to commit horrific atrocities without conscience.

Yet as major wars pass from living memory into recorded history, our direct connection is physically severed and a tangible part of human emotion becomes pure imagination *(aided only by the written word and documented recordings [since the emergence of 'war photography' in 1850s])*. When the last survivor of a wartime battle finally passes away, what were once very real hostilities are only recalled by those who choose to *remember* historic conflicts through 'second-hand' knowledge, as memories of sickening barbarity and euphoric exultation are ultimately lost forever. Such defining human moments however are accessible to anyone with the foresight to peer into the *'collective unconscious'*.

Unfortunately it appears that, as a politically and religiously divided species, we are incapable of living in harmony without the desire to retain effective military force *(which is invariably abused by the leaders of many nations)*. The only realistic hope for the future of humanity is to form a collective wisdom that strives to work together and avoid all future wars at any cost. Only then can we possibly be equipped to confront the other enormous challenges that we have brought upon ourselves *(such as climate change, pollution and loss of biodiversity)*.

In today’s ‘modern world’ the mass media *(be it ‘social media’, ‘broadcast media’, or the ‘press’)* is the primary vehicle for our intellectual understanding of local, regional and global conflicts. Whilst the factual reporting of regional conflicts is increasingly being restricted, censored, misreported or fundamentally altered by different authorities around the world *(for the purposes of propaganda and the support of a target audience)*, genuine news reports by trusted independent sources can provide an invaluable historic record of the consequences of war. Indeed, contemporary journalists can help to preserve the human experience of war; making it easier to perceive for future generations ~ just as archive film footage of 20th century wars can remind us not to repeat the deadly mistakes of the past that brought so much suffering to our forebears.

By cherishing factual documentaries that show the true horrors of war, the conditions suffered by those fighting for their lives becomes more tangible. Although it is impossible to ‘re-witness’ historic moments personally, common wartime events *(such as life in the trenches on the ‘Western Front’ during the Great War, and the persecution of millions of unfortunate civilians during World War **II**)*, are made more conceivable by seeing the horrors unfold on celluloid before your eyes. Indeed archived reports can provide future generations with historic evidence regarding the consequences of choosing conflict over diplomacy. They clearly show just how a well-intended call to arms can easily degenerate into an appalling man-made hell for millions of people.

One shining example of archive footage preserving the realities of an historic war is evident as New Zealand-born producer and director **‘Peter Jackson’**s centennial documentary ***‘They Shall Not Grow Old’*** *(2018).* This masterful restoration of original film, which had been digitally improved and colourised, brought to life the Great War exactly a century after it had ended. A vast majority of earlier wars however were not captured on film ~ a revolutionary visual medium that allowed unfolding horrors of the past to be glimpsed in the present. Although we have many preserved wartime monuments and artefacts, film footage was not available before the conflicts of the 20th century, so the omnipresent horrors of earlier wars were more easily misconceived once they had passed beyond living memory. Indeed, throughout the centuries, many bloody wars *(particularly in Europe)* have followed in relatively quick succession, as subsequent generations repeated the experiences that had been lost by the passing of elders with first hand memories. Unfortunately it is clear that archive film alone cannot prevent the tragedy of war from continuing to rear its ugly head around the world.

The incredibly complex human mind has countless facets, but our unique way of perceiving the world can essentially be broken down into two basic states of thought. The idea of *‘positive’* and *‘negative’* broadly represents the polarisation of human thought ~ vis-à-vis *‘constructive’* and *‘destructive’* aspects of the mind such as *‘friendship’* and *‘war’*, *‘joy’* and *‘despair’* or *‘love’* and *‘hate’*. A vast majority of citizens of the modern world currently live in societies which morally support the positive aspects but struggle to defeat the negative.

Whenever negative ambitions are imposed upon a society *(either by internal or external forces)*, its population will invariably feel the consequences ~ with most political or diplomatic transgressions resulting in a conflict of some kind. Governments or other belligerent organisations that embark on this path will always justify their actions through various means of mass communication in order to retain support of their people who will have largely 'sensed' the impending turmoil. Should a conflict be serious enough to descend into a full-blown war, then this *'propaganda'* will almost always focus on a perceived moral breakdown of their enemies. Yet, no matter how 'morally right' a warring party may feel, through the very act of declaring war, they are complicit in exploiting cultural values to force negative emotions upon their people. As such, in most prolonged conflicts, humanity is readily lost, and behaviours that are seen as totally unacceptable in peacetime can become regarded as the norm. Dignity and respect are amongst the first human notions to be lost as order descends into chaos, and everyday life becomes dominated by powerful negative emotions such as hate, anger, sadness. and greed. Indeed ordinary citizens can themselves be overcome with feelings of power or revenge *(particularly when they are caught up in civil wars)* with recent conflicts in places such as Rwanda, Kosovo, and Syria seeing many thousands of people being murdered by their neighbours.

The reasoned state of existence that we collectively share as responsible adult human beings is finely balanced. Yet as civilisation has grown over the decades, it has severely tested the psychological stability of various populations around the world. Each new generation inherits a society more knowledgeable and technologically advanced than the last, but also faces new challenges that may have lain far beyond the comprehension of those who came before. Furthermore, whilst benefiting from ancestral knowledge and wisdom, the 'modern' psyche is also burdened with humanity's compulsive desire to improve destructive technology. The evolution of modern life is such that *'philosophy'* and *'invention'* have broadened both the positive and negative aspects of human behaviour and achievement. The immediate military application of new sciences exemplifies that fact. As the collective power of human thought evolves, there is every chance that any number of powerful nations could get swept away with an irresistible negative emotion, and start a war that global civilisation simply cannot survive. With today's most advanced modern weapons capable of unimaginable destruction, a single catastrophic event has the potential to end our reign as the planet's dominant species. It may appear fatalistic, but alas human history indicates that this will, most likely, eventually happen.

As the end of global civilisation *(and the current world order)* approaches, so a sense of morbid realisation will begin to pervade our collective consciousness ~ with a growing number of people starting to believe that some sort of *'Armageddon'* is inevitable. Paradoxically, this very belief increases the likelihood that an apocalyptic event *(such as a nuclear war)* will actually happen, as disturbing negative overtones pervade society and unbalance our sense of 'common reasoning'. It is our collective consciousness that will most likely tip modern civilisation over the proverbial edge. Most citizens *(certainly in Westernised countries)* will see the end coming in the weeks and days leading up to a catastrophic global event, with only politicians and military leaders likely to deny the increasing probability. Belief, however is a powerful, and ultimately deadly, human trait.

To date only two ‘small’ atomic bombs have ever been detonated in anger, and that was back in 1945. Yet our ‘civilised’ existence since the end of the Second World War has continued under the ever-present shadow of a ‘nuclear deterrent’ ~ with a growing number of countries capable of using nuclear weapons against their enemies. Indeed with international relations between various military powers no longer bound by Cold War protocols, the relative stability of today’s modern civilisation *(and the thriving global economy that powers it)* is looking increasingly precarious. Moreover, we now live at a time when virtually no one on the planet *(bar the diminishing number of living survivors from Hiroshima and Nagasaki)* has ever actually witnessed a nuclear attack.

The fact that there has not been a nuclear exchange since 1945 does not prove that nuclear deterrents will continue to work indefinitely. Indeed, as nuclear technology becomes more accessible and the components for sophisticated weapons become more readily available, the illicit activities of smaller state players *(and large criminal organisations)* increase the chances of a devastating nuclear attack happening again. Of course the likelihood of further nuclear attacks is greatly increased after an initial strike has broken the moral *(and psychological)* constraints and taboos of ‘first use’.

Should the demise of modern civilisation follow a path to mutual annihilation and succumb to a self-fulfilling orgy of nuclear Armageddon, it is highly likely that in the preceding days and weeks, the population at large *(particularly in ‘better informed’ developed nations)* would start to feel a growing sense of urgency and desperation as events unfold. Irresistible stress, and a realisation of ‘the inevitable‘ would likely burden society in the final days before an oncoming nuclear war ~ though most people living in a country under attack would no nothing about the first wave of strikes.

Imagine yourself in the position of being woken at night by a very bright light. However, just as your waking consciousness takes focus, you start to feel an intense heat then ...nothing as your living body is instantaneously overwhelmed by an explosion that completely obliterates your entire physical realm.

It is very difficult to live a contented life when you are continuously made aware that today there are thousands of unimaginably powerful warheads in active service ~ stationed at airfields, in submarines, and in missile silos around the world. Any one of these can be readily armed and programmed to detonate in your vicinity should certain enemies of your nation feel the need to do so. A vast majority of people continue their daily lives without pondering such a horrifying possibility. Indeed most people *(at least in the developed world)* are fully aware that civilisation is at the mercy of a global nuclear conflict which can essentially be started with the *‘turn of a key’* and/or the *‘push of a button’*. Yet almost everyone will put such thoughts to the back of their mind and will not generally consider such an uncomfortable truth about the world that we live in. This, however, is effectively acting ignorant to just how vulnerable, in reality, we all are to the destructive will of other human beings.

'Denial' is an innate cognitive bias that helps us to avoid contemplating 'unacceptable truths' ~ such as the utter destruction that a self-inflicted nuclear Armageddon would inevitably bring. Whilst the act of 'denial' *(in the face of factual evidence)* is readily contrived by politicians and religious leaders to manipulate the masses, genuine denial is a psychological defence mechanism that helps us, as individuals, to maintain our 'sanity'. Indeed our conscious refusal to acknowledge the unpalatable truth about any prospective nuclear exchange is fundamental to our collective reality. In fact nuclear Armageddon is such a distressing possibility that the very act of thinking about it strengthens our refusal to believe that it could easily happen in our own life time. So powerful is the emotive response of denial that, even in the aftermath of a nuclear war, a significant proportion of survivors may still refuse to believe that it has actually happened.

Most people today share a fatalistic view towards our probable demise; believing that there's not much that the average citizen can do to stop nuclear annihilation once we have been set on that path by *'higher powers'*. This passive attitude towards nuclear deterrence is convenient, but enormously dangerous when you consider the ever-changing risks that are posed by the daily onslaught of new dangers that cumulatively threaten our continued 'civilised' existence.

Whilst constant paranoia certainly added to the potency of nuclear rivalry between the United States and the Soviet Union during the Cold War, it always focused straightforwardly on the possibilities of a catastrophic exchange between East and West. The political dynamics of today however are far less simplistic, with a complex network of international relations *(both diplomatic and economic)* between various nuclear powers creating a fluid situation that could play out any number of ways. Since the start of the 21st century, not only have tensions continued to rise between the foremost Cold War rivals, but various new threats have emerged, with nations including Israel, Pakistan, and North Korea gaining an ability to bring utter devastation to their regional enemies should they so wish.

Be it nuclear, chemical or biological, the technologies that enable weapons of mass destruction are becoming more difficult to manage. The advent of global electronic communications, along with advances in areas such as *'AI software'* and *'3D printing'*, have made destructive technology more readily available to organisations that are hostile to the current world order. Indeed as **WMD**s become increasingly easier to acquire, so does the likelihood that a turn of catastrophic events will ultimately bring about the collapse of modern civilisation. With many extreme ideologies capable of showing complete disregard for human life *(unless it fits their model of the world)*, there is the ever-present danger that our capacity to commit despicable acts of inhumanity against one another could ultimately be the downfall of our species. Unfortunately, unlike a vast majority of the human race, many fanatical devotees of extreme religious belief or political ideology have little or no sense of self-preservation.

Playing out over no more than a couple of months at most, the prelude to any future 'end-time' conflict will accompany a growing realisation that humankind is staring over the precipice. As modern civilisation begins to falter, the most likely scenarios all envisage a sharp rise in conflicts around the world leading up to the final weeks. With a growing number of devastating regional wars *(along with major pandemics and widespread famine in developing nations)* having placed enormous stress on the global economy, many wealthier countries will become increasingly insular. As our civilisation stumbles towards its final days, trillions of dollars will most likely have been wiped off stock exchanges around the world, and with confidence lost *(and international trading reaching an unsustainable 'low')*, it will have had a snowball effect ~ leading to the inevitable collapse of world markets. With essential natural resources invariably running out, many societies will start to crumble, and a rising number of countries will succumb to what will be the ultimate energy crisis. As trade routes collapse and mass starvation takes hold in many nations, there will be growing international distrust. Indeed the state of world affairs would no doubt build to a psychological crescendo which would become so intense that everyday people would now recognise that the 'end' is indeed 'nigh'. In fact, an acceptance that the 'inevitable will happen' is an intellectual prerequisite for any 'third world war'. Although that time is not imminent *(at the writing of this book)*, over the past few decades there has been a marked shift in public opinion regarding the prospect of any future nuclear war. This has moved from 'total denial' *(that is; that such an event was highly unlikely)* to one of 'plain ignorance' *(that is; comprehending the likelihood, but not wishing to think about it)*. Our collective consciousness is gradually moving towards a state of undeniable realisation.

Whilst we, as a single species of hominid, may well bring about our own downfall, life beyond humanity will inevitably survive in some form. Indeed nature is all about survival, and life, with or without our presence, will go on. It is interesting that whilst the number of extant species amounts to less than 0.1% of **all** species that have **ever** existed on Earth, life in the present geological period remains the most diverse in our planet's history. Along with sudden climate change at the start of the Holocene epoch, only the activities of human beings has significantly reduced that number, yet approximately 8.7 million different species still exist on Earth today. As conditions on the planet have changed over geological time, so new species of life have continually evolved ~ filling new niches for survival and, in the process, often replacing dead or dying populations of entirely different species. In fact, whilst present human activity is causing irreparable damage to the natural world, there have been at least five comparable mass extinctions, as well as countless smaller extinction events in Earth's long history.

Unlike all of the other extinction events that came before however, this one is playing out under the 'stewardship of a thinking species'. Perhaps our only 'saving grace' is our ability to rationalise. Indeed we are the only species capable of contemplating our own demise and therefore able to take steps to avoid it. Yet, as a thinking species, our continued inventiveness is persistently directed towards killing other human beings, with science and technology put to work on various military ambitions around the world. This innate urge to dominate perceived enemies through military might, demonstrates an inclination towards violence that is not repeated anywhere else in the animal kingdom *(with perhaps the exception of chimpanzees ~ our closest genetic relatives)*. Were it not for negative emotions such as 'distrust', 'greed' and 'hate', there would be no need for armed forces, and our biggest threat to the planet would only come through 'ignorance' and 'wilful neglect'. Alas by combining 'intellectual prowess' with base 'animal instincts' the human species is responsible for deadly ingenuity ~ with a capacity for destruction that is bound only by the size of our home planet.

Should the downfall of humanity be so violent or prolonged as to wipe out all advanced life on Earth *(including all mammals, reptiles birds and fish)*, the process of natural evolution will continue with any 'lower' life forms that may survive. Barring any extreme cosmic events, our living planet has a 'shelf life' of around another 2½ billion years or so. Indeed as poison atmosphere gives way to a growing biosphere, the natural world will gradually recover. Entirely new species will, over time, emerge ~ arising from the need to adapt and fill new 'niches of survival'. If, hypothetically, sentient life were to again arise over the next few 100 million years or so, it will inherit a completely different planet Earth. Were it to evolve intelligence, it would no doubt wonder what happened to our species, just as we ourselves have an engaging curiosity about the age of dinosaurs and other animals that once dominated the planet. Wherever our 'fate' lies, maybe our final legacy will be to warn our successors of the ultimate cost of abusing the responsibility that comes with conscious thought.

An ethereal footnote of subconscious thoughts

One thing is inevitable, we will all face death. Whether it cuts life short or ushers a natural ending to life, death will happen. When we die, the last part of us to invariably stop working is the subconscious mind and, for most people, the final thing that they witness in life is a dream or hallucinatory vision. The length of this *'closing down'* of the mind depends on how we die ~ prolonged in slow death, but split-second in cases of sudden death. Yet, however we die, the brain almost always passes through a beta-delta *(dream-like)* state before being consumed by the emptiness of death. Indeed people who have recovered from near-death experiences *(such as those who have been resuscitated after losing their heartbeat, or have emerged from a deep coma)* can always recall a dying dream *(which often includes leaving their physical bodies behind)*.

When a massive injury to the brain itself causes instantaneous death, of course a 'dying dream' is simply not possible if the victim is completely unaware of their impending doom. In such cases, there can be no physiological transition from life to death, and our waking reality is lost in an instant. Whilst only a small minority of deaths occur this way, a nuclear war could bring instant death to hundreds of millions of people at a stroke. Billions more, however would likely suffer a slower, agonising death during which time our collective waking reality will have been lost. Yet it is impossible to really know *(without witnessing at first hand and surviving to tell the tale)* what it's like to experience a nuclear attack, and how the human collective consciousness will hold up amongst a few dying survivors.

Now here's an *(unscientific but intuitive)* assessment of our ethereal existence in a harsh physical world that is capable of sustaining such powerful nuclear fusion reactions. For people closest to such an explosion, death would happen immediately as they are instantly vaporised *(with absolutely no time for their brains to shut down)*. The thermal radiation of a typical one megaton bomb could incinerate everything within a forty mile radius of detonation, and those caught within the initial blast range would likely know absolutely nothing of it. One moment they'd exist as a living 'physical' being, the next moment the atomic particles that once made the cells of their bodies are helping to fuel an unstoppable chain reaction. As fragile as the human body may be however, like everything else its demise will leave an 'imprint' because, whenever 'pure energy' vaporises matter, it will always 'mimic' its structural pattern at a subatomic level *(as the physical entity is instantaneously overwhelmed)*. Whilst our physical state as a living organism is extremely fragile, the human mind is essentially an evolved series of electrical impulses. Therefore, when every last cell of an individual is vaporised by a nuclear explosion, at the moment of impact, fusion energy consumes their very 'essence', and *(although life cannot follow)* every atom that was once part of their physical existence effectively enters another dimension that is completely devoid of matter and any sense of physicality.

In our ‘physical world’ *(which can sustain fragile biological life)* atoms provide the fuel for all forms of energy, which *(as a conserved quantity)* is in turn relied upon for the existence of all physical ‘matter’. It is the fusion of atomic nuclei that produces the most powerful release of energy possible in our physical dimension. Indeed nuclear fusion is a universal process, which powers all stars, and the most energetic of all cosmic events *(supernovae)* can occur when they eventually die. These unimaginably powerful events are both the creators and destroyers of atomic matter. Not only are they responsible for the abundance of heavier elements in our physical Universe *(through the process of nucleosynthesis)*, but the largest of all can actually break the boundaries of our physical dimension through the creation of ‘black holes’.

Beyond an event horizon *(which defines the size of all black holes)* even black body radiation cannot be emitted. However, whilst they may appear to reach thermodynamic equilibrium, the radiative distribution of entropy inside a black hole will actually continue in another *(mirror image)* dimension whose physicality has been completely separated from ours. The curious thing is that, whilst no physical atoms *(and certainly no living creature)* could ever pass through a black hole and survive intact, the human mind has managed to peer into dimensions beyond our own. Indeed our ability to perceive the world, not only through the physical necessities of being an advanced biological life form, but through abstract thought, imagination, knowledge and invention has allowed modern human beings to effectively forge an ethereal ‘non physical’ path into the alternative dimensions that lie beyond black holes.

What follows is a profound reflection on the growing chaos within market economies, and modern society as a whole. The complexities of human development have increased tremendously over the past few millennia, and today’s global civilisation is more elaborate and perplexing than it has ever been. Like any activity human civilisation conforms to the universal laws of nature, and its growth represents an expression of thermodynamic quantity. Indeed, the modern world could be regarded as an ethereal consequence of entropy. We live on a planet which is ultimately a closed system, and as society becomes more populous and technologically advanced whilst habitable land and essential natural resources dwindle, civilised life inevitably becomes more chaotic.

Besides having to deal with the physical constraints of modern civilisation, as a species we are confronted with growing psychological and physiological pressures in order to preserve the ideals that power today’s modern economies. Over the past few centuries ‘Westernised’ societies have largely broken the shackles of religious impediment and have become less rigid and more complex. Over a billion people today live freer open societies that promote greater tolerance towards minorities, and have relaxed attitudes towards historical taboos. However this conflicts with the traditional opinions and attitudes of many millions of citizens ~ creating volatile mix of different radical beliefs. As a result, global civilisation in the early 21st century has not only incited a backlash of ‘moral righteousness’ from different religious groups around the world, but it has had to endure a dramatic rise in extreme political views. Our ability to work together for mutual benefit is what binds modern global civilisation, but it is under growing pressure from ferocious regional wars, dwindling resources, and the devastating effects of anthropogenic climate change which exacerbate a lack of fertile land and fresh water.

Were it not for modern civilisation, a vast majority of the global population *(of over 8 billion people)* simply could not survive. Conversely by relying on our fragile civilisation, humanity has placed itself in a very precarious situation. Whenever ordered systems break down and chaos ensues, death and destruction inevitably follow. Yet, whilst increasing entropy introduces ever more chaos to our human world, the umbrella of civilisation still largely protects our species from the ravages of nature. Although there may be less cohesion, all chaotic systems simply adhere just a more complex set of logical circumstances, and modern civilisation is heading inexorably towards just such a state. Ultimately however chaos is fundamental to the destruction of physical existence, and mankind’s ultimate expression of chaos is nuclear war.