Obese Planet: what our bodies tell us about global heating

John Hughes

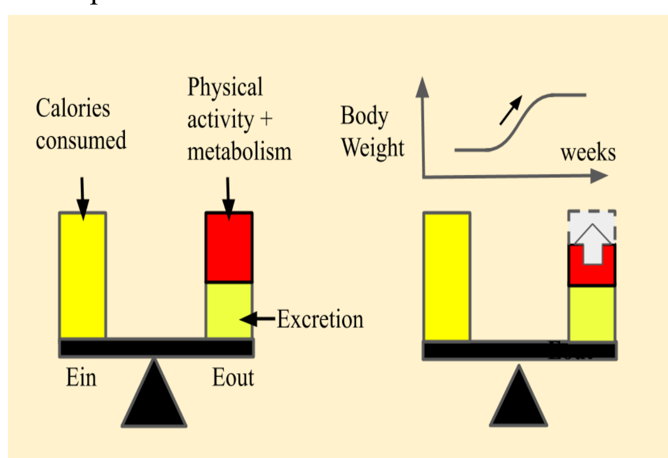
"I just want people to listen to the science"

So said Greta Thunberg, the world-renowned climate activist, in her address to an Extinction Rebellion meeting and members of parliament in London during 2019. Likewise, perhaps especially, that message is for our policymakers: when faced with an impending crisis such as climate breakdown or the obesity epidemic, they must ensure their decisions are informed by evidence and facts rather than sentiment and opinion; reason rather than emotion. Science tells us that Earth has a limited lifespan and that the life it supports will end sooner unless our governments commit to environmentally sustainable policies. Likewise, we humans have a limited lifespan and science tells us that our lives will end sooner unless our governments adopt policies that encourage healthy lifestyles. It would seem that safeguarding our living planet or ourselves requires a similar mindset, so does this suggest some sort of underlying relationship? Physically, of course, the systems controlling our planet's and our body's wellbeing are quite distinct, with different system parts each with different interdependencies, and with vastly different time lags. But the dangers they confront and the protections they have evolved turn out to be uncannily similar. Could it be that these two apparently disparate systems are merely different manifestations of the same system?

This essay sets out to test this hypothesis by highlighting the similarities, simultaneously helping us to 'listen to the science' of global heating. Then, analogy is used to show how the better understanding we have for our own wellbeing can warn us of dangers and suggest safeguards to restrain future global heating. Analogy worked for Charles Darwin, who used it to help explain his theory of natural selection, so why not here?

Science: the balance of power

We start with some simple science, the first law of thermodynamics, which states that energy can be neither created nor destroyed, merely transformed from one type to another. The human body and Earth's biosphere, that thin layer of land, sea and air that supports all life, are no exception: when they receive energy faster than they give it out they must accumulate the surplus within the system, the way a bank accumulates our surplus cash when income exceeds outgoings. But, unlike a bank, which allows that surplus to accumulate indefinitely, our two systems respond in a way that eventually eliminates the surplus.



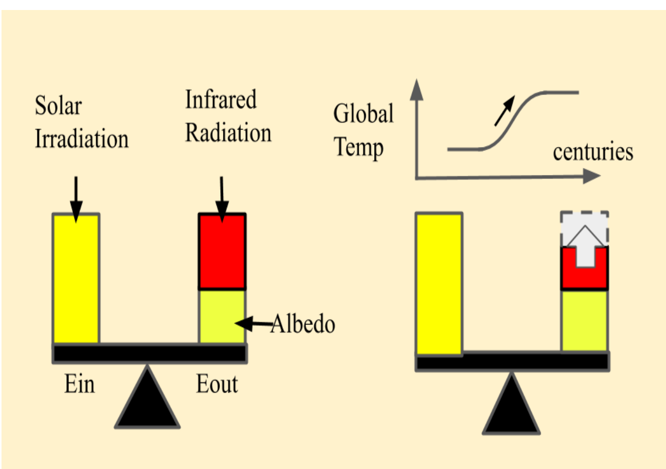
(a) Weight stable **(b) Weight increasing**

Fig. 1 Our body's energy balance

For our bodies, the incoming energy comes mostly from the calories we consume and the outgoing energy comes mostly from our basal metabolism

(BMR), physical activity and our excretion.[1] If the incoming energy matches the outgoing energy, Fig.1(a), our weight remains constant, but if we reduce our outgoing energy by being less active, Fig.1(b), there is an energy imbalance and the surplus must be accumulated in our body, mostly as fat. As our weight starts to rise so does our basal metabolism and the calories used for our lowered activity, and when the total outgoing energy again reaches the level of the incoming energy, equilibrium is restored and our weight settles to a new, higher value. Unlike our ancestors, today's affluent societies around the world have easy access to calorie-dense foods and reduced physical activity, and our population's weight is on the rise.

For our planet, the incoming energy comes from the solar irradiation it receives and the outgoing energy comes from infrared radiating from its heated surface and atmosphere, and solar radiation reflected from the clouds and ground (albedo).



(a) Temp stable **(b) Temp rising**

Fig. 2 Earth's energy balance

[1] Depending on our food preferences, the waste we excrete contains between 20% and 60% of the calories we consume. This has been used to run a bus service in Bristol, using biomethane produced from human waste, the so-called 'poo bus' service.

If the incoming energy matches the outgoing energy, as shown in Fig. 2(a), the mean surface temperature remains constant, but if we reduce the outgoing energy by blocking the infrared radiation with greenhouse gases in the atmosphere, there is an energy imbalance and the surplus must be accumulated in the biosphere as heat (the greenhouse effect). As surface temperature starts to rise so does the infrared radiation, as shown in Fig. 2(b), and when the total outgoing energy again reaches the level of the incoming energy, equilibrium is restored and the mean surface temperature settles to a new, higher value.

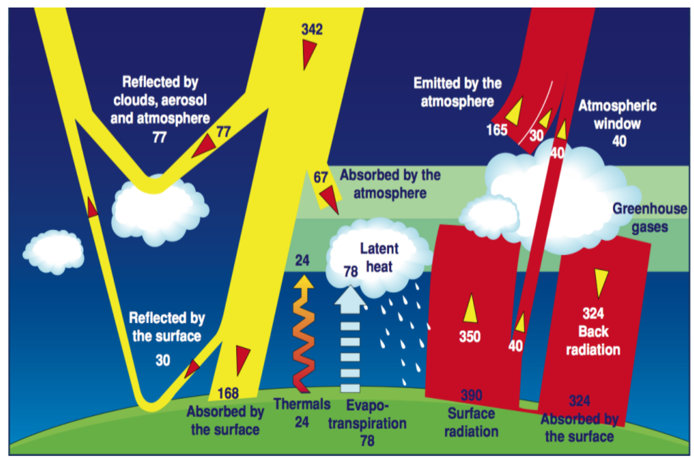


Fig. 3 Earth's equilibrium energy flows

Fig. 3 shows the Earth in energy balance with mean solar irradiation at the top of the atmosphere at the rate of 342 W/m^2 balanced by infrared radiation of 235 W/m^2 and albedo of 107 W/m^2 leaving the top of the atmosphere. Today's energy-hungry societies are burning fossil fuels so fast that their greenhouse gas emissions (mainly carbon dioxide) are causing an energy imbalance of about 0.75W/m^2 and while this is only about 0.25% of the incoming energy it is nevertheless heating our planet at an alarming rate.[2]

[2] The apparently small energy surplus gives a global imbalance of 380 trillion W, equivalent to the power output from 120 thousand Hinkley Point C nuclear power stations each generating 3.2GW

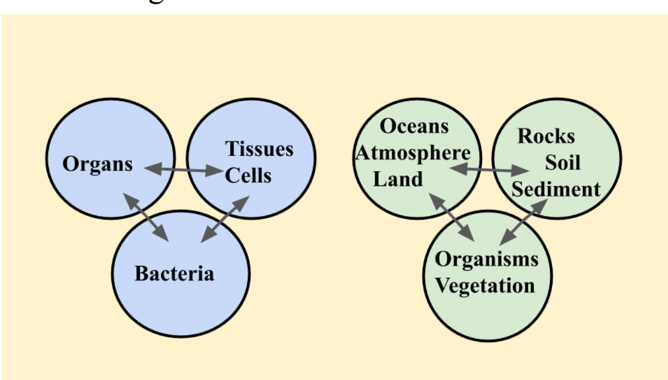
Our systems have demonstrated equivalence by:

- absorbing, by digesting or heating, about two-thirds of their incoming energy.
- emitting, by working or radiating, about two-thirds of their incoming energy.
- ejecting, by excreting or reflecting, about one-third of their incoming energy.
- accumulating, as fat or heat, surplus energy while finding a new balance resulting in increased weight or surface temperature.

So, does this mean our two systems are at the mercy of science? There is no escaping the link between energy surplus and weight gain or temperature rise but all is not lost because our two systems have evolved mechanisms for reducing the surplus energy and so regain a measure of control. To understand how this has been achieved we must take a look inside the systems.

Resilience: taking back control

Each of our systems is *complex* which means they have a large number of interdependent parts, as shown in Fig.4.



(a) Body (b) Planet

Fig.4 Interdependent parts of systems

For our bodies, Fig.4(a), the interdependent parts include our organs, our cells and tissues, and the bacteria that comprise the human microbiome. Communication between the parts is achieved by our autonomic nervous system and our endocrine (hormone) system. Likewise our planet, Fig.4(b), has interdependent parts which operate across various levels:; oceans, land and atmosphere; surface rocks, soil and sediments; organisms and vegetation, interconnected by the planet's heat engine which produces the carbon and water cycles as well as the thermohaline circulation (THC) and trade winds.

When one part of a system changes the state of another and that part in turn changes the state of the first, we have a feedback loop and these play a pivotal role in determining how each system responds to an energy surplus. When the feedback diminishes the system's response to a disturbance, making the system less sensitive and more stable, we have a so-called negative feedback loop. When it amplifies the response, making the system more sensitive and less stable, we have a positive feedback loop. Familiar examples are our motor car's 'cruise control' which uses negative feedback to regulate road speed, and 'servo-assisted braking' which uses positive feedback to make braking more sensitive.

Our bodies have evolved the ability to withstand many types of disturbance because we are able to self-regulate our body's internal environment, indicated by biological set-points such as body temperature, blood pressure and blood glucose level which are controlled using a system of negative feedback loops called 'homeostasis'. As an example, our core temperature is detected from the blood flowing in our brain (in the hypothalamus) which controls it by instructing glands to sweat when we are hot (to lose heat through evaporation) or muscles to shiver when we are cold (to generate heat through raising our metabolism). Another negative feedback loop controls our blood glucose level, and causes the pancreas to secrete insulin when the level is high to enable cells to absorb the excess and when the level is low it causes the pancreas to secrete another hormone, glucagon, which causes the liver to release glucose to restore the level in the bloodstream.

We have positive feedback loops too. When we feel stress or perceive danger our brain instructs our adrenal glands to secrete the hormone adrenaline which raises our heart rate, blood pressure and blood glucose level to prepare us for 'fight or flight'. Other positive feedback loops are associated with our brain's reward pathway (located in the brain's limbic system) and have evolved to subserve activities essential for our survival, such as reproductive or feeding behaviour. These activities produce the neurotransmitter dopamine in the reward pathway and this produces a feeling of wellbeing which encourages us to do more of the same. Feeding behaviour is of particular relevance here and is interesting because it uses both negative and positive feedback loops, as shown in Fig.5.

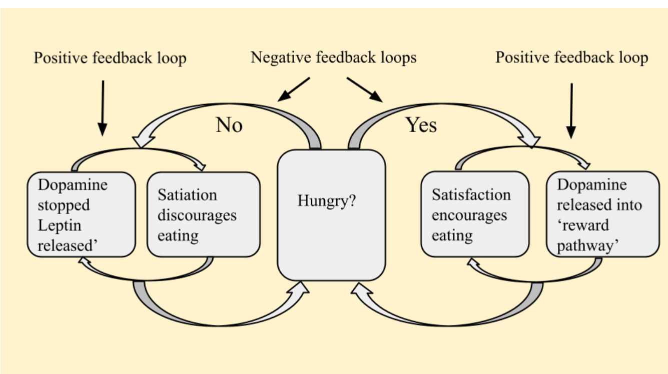


Fig.5 Self- regulating feeding behaviour

During a palatable meal, our heightened sense of taste, smell and texture trigger the release of dopamine and the feeling of satisfaction encourages more eating. But as the stomach fills, this is sensed by nerve receptors in the stomach wall and they transmit signals via the vagus nerve to the brain to produce the feeling of fullness which eventually tells us to stop eating. This is accompanied by the release of another hormone, leptin, which moderates the effects of dopamine to further reduce appetite. Overall the feeding behaviour is regulated by the negative feedback loops but the process is made more responsive by the amplification provided by the positive feedback loops

Like our bodies, our planet has evolved a self-regulating system to safeguard its internal environment by stabilising global set-points such as surface temperature, atmospheric composition and humidity, and ocean alkalinity and salinity. Regulation is achieved by a tightly coupled system of negative feedback loops called Gaia. The Gaia theory postulates that the biosphere and organisms have co-evolved to create an environment in which all life-forms can thrive. The operation of the complex network of feedback loops still leaves much to be explained but some generalities are well established. For example, the remarkably stable oxygen level in the atmosphere (20.946%) is believed to be due to the balance between photosynthesis, which produces oxygen, and respiration, which consumes it. By contrast, the atmosphere's relative humidity, being a very strong function of temperature, can vary from nearly 100% in the humid tropics to nearly 0% in an arid desert. But it maintains a near-constant average of about 60% due to a balance between the water vapour added to the atmosphere from ocean evaporation and plant transpiration, and the water vapour removed by rain or snow. Surface temperature varies greatly around the planet but the global average has been held at around 15°C and atmospheric carbon dioxide at around 0.028% (280 parts per million) throughout the pre-industrial Holocene by a self-regulating feedback loop as shown in Fig. 6. The temperature regulation depends on achieving a balance between, on the one hand, the release into the atmosphere of carbon dioxide resulting from respiration, the decay of organic matter, and volcanic and tectonic activity, and on the other hand, the removal and storage of carbon dioxide due to photosynthesis and the chemical weathering of rocks by acid rain.

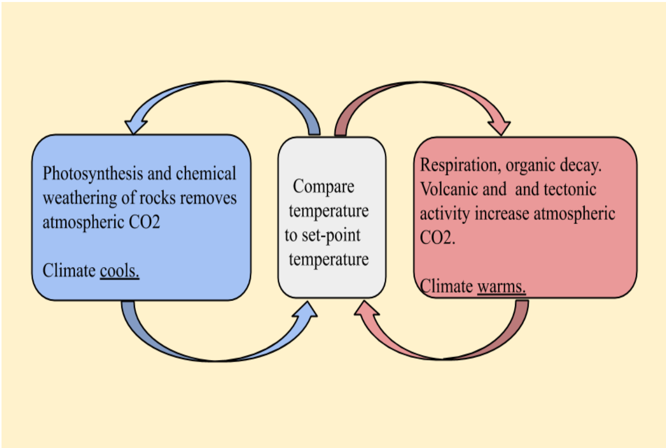
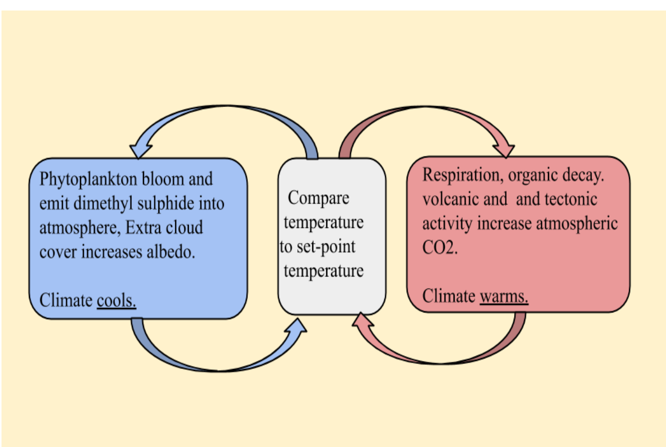


Fig. 6 Self-regulation of temperature by chemical weathering

It has been further shown that the rate of weathering is increased by rising temperature and by the presence of bacteria, implying that the set-point temperature might be the one that best helps the bacteria to thrive.

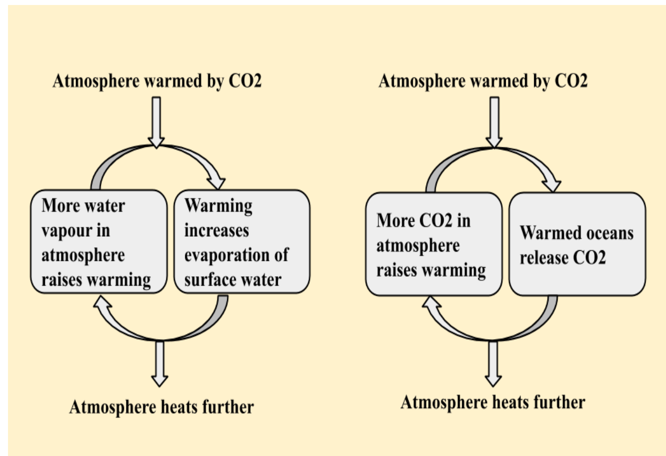
Further, Lovelock et al have proposed that the ocean's phytoplankton could explain the planet's temperature self-regulation, as shown in Fig. 7.



Fig, 7 Self-regulation of temperature by albedo

As oceans heat, their phytoplankton bloom and excrete more sulphur compounds (dimethyl sulphide) which when oxidised produce cloud-forming nuclei. The consequent increase in cloud cover reflects more of the incoming sunlight away from Earth, producing a cooling effect and closing the negative feedback loop to create thermostasis. The set-point temperature of the control loop is likely that which best suits the phytoplankton.

Positive feedback increases the sensitivity in both the warming (pink) and cooling (blue) loops and two such mechanisms are shown in Fig.8.



(a) Water vapour **(b) Ocean CO_2**

Fig, 8 Earth's positive feedbacks

The most powerful of these is the so-called water vapour feedback which arises because as the atmosphere heats it is able to hold more water vapour, another potent greenhouse gas, Fig. 8(a). Secondly, as the oceans heat, their carbon dioxide becomes less soluble and is released into the atmosphere, Fig. 8(b). Finally, as the polar regions heat, reflective sea-ice melts and is replaced by dark sea which absorbs more of the sunlight's energy (ice-albedo feedback). All three are 'fast' positive feedbacks because they act immediately to amplify the heating forced by increased carbon dioxide.

As with our body's self-regulating feeding control our planet's temperature is regulated by the negative feedback loops but the process is made more responsive by the amplification of the positive feedback loops.The significance of this can be gauged by its impact on what climate scientists call ‘climate sensitivity’, defined as the equilibrium temperature rise resulting from doubling the carbon dioxide concentration in the atmosphere, which can be amplified by climate feedbacks by as much as fivefold [3]. So, while carbon dioxide is responsible for the forcing of global heating, positive feedback has a bigger impact on temperature rise.

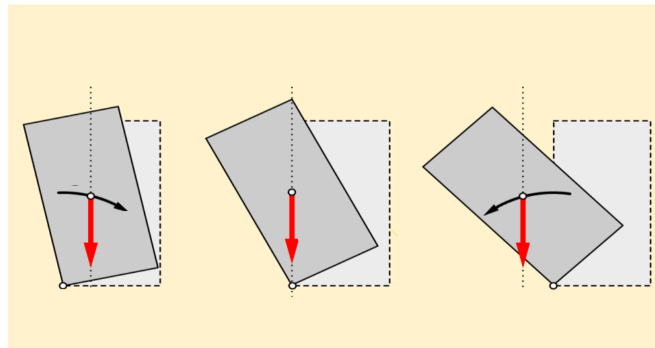
Our systems show equivalence because they both:

- are complex with a hierarchy of interdependent parts.
- have evolved set-points, biological or global, for sustaining their internal environments.
- use negative feedback loops to self-regulate their internal environment, through homeostasis or Gaia.
- use positive feedback to improve system responsiveness.

It might appear that our two systems are well equipped to deal with all types of energy imbalance. But they have been described so far assuming linear behaviour which does not hold for larger energy imbalances such as those causing the obesity epidemic or the climate emergency. There are circumstances under which our system’s self-regulation mechanisms do not cope, leaving them unprotected and vulnerable.

Vulnerability: losing control

We can start to appreciate the dangers lying in wait for either our bodies or the planet by considering the behaviour of an object on a table (Fig. 9).



(a) Stable **(b) Tipping** **(c) Unstable**

Fig. 9 Illustration of tipping point

If it is pushed *gently* on one side (Fig. 9(a)), it will lean a little and, when released, will return safely to its original position of rest. The response is linear and stability is ensured by the negative feedback afforded by gravity. But if now the object is pushed further, the negative feedback decreases progressively, eventually ceasing altogether when it reaches the 'tipping point' shown in Fig. 9(b). Beyond this point gravity becomes a positive feedback and, with no negative feedback to maintain control, the object topples onto its side (Fig.9(c)), a state from which it has no way to recover. This simple example illustrates a problem that exists with all complex systems: if their negative feedback loops become sufficiently weakened, they may lose control and allow positive feedback loops to become dominant, rendering the system unstable. Our bodies and planet are no exception.

To understand how this problem manifests itself in our bodies we must first examine the feeding traits we have evolved over the past 2.5 million years, as shown in Fig. 10. For virtually all that period our

[3] Physicists calculate the climate sensitivity (using Planck's Law) for Earth treated as a ‘black body’, i.e. devoid of feedback effects, to be 1.2ºC. When deduced empirically from paleoclimate data the sensitivity for ‘fast’ feedbacks is typically around 3ºC and if ‘slow’ feedbacks (eg. ice sheet disintegration, vegetation migration and greenhouse gas release from soil, tundra and ocean sediment) are included this would rise to typically 6ºC (a fivefold increase in climate sensitivity).

forebears lived as ‘hunter-gatherers’ foraging for any available palatable food, perhaps feeding on the likes of termites, edible roots and berries, and stalking rabbits or hunting bison or mammoths. Often scarce, their food was nevertheless varied and nourishing, and the only available high-calorie sweet food would have been ripe fruit or honey.

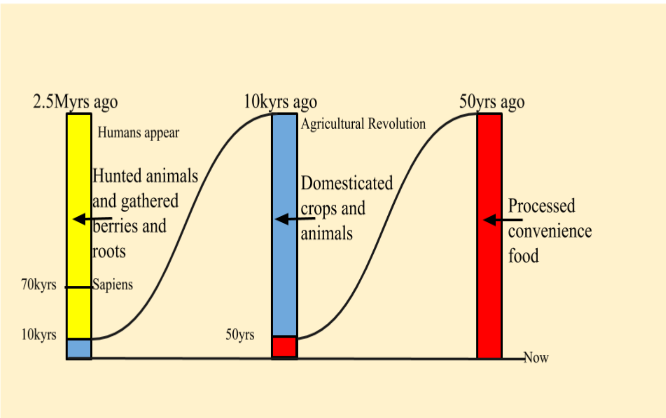


Fig. 10 Timeline of human food consumption

The arrival of the Agricultural Revolution about 10 thousand years ago brought shifts towards farming and herding to produce ‘domesticated’ plants and animals, and diets became less varied, often limited to the farm produce. Today, our lifestyle has led to diets dominated by industrially-processed food that is made palatable by its high fat or sugar content. Most of our calories now come from ultra-processed foods (UPFs).

The feeding self-regulation evolved by our ancestors (see Fig. 5) used negative feedback to maintain overall control but with the amplification of their reward pathway’s positive feedback encouraging them to gorge whenever possible. This helped them survive periods of food scarcity, a successful strategy which became hard-wired in their genes and retained by us ever since. But whereas our ancestors thrived on a low calorie, high nutrient diet, we are now trying to thrive on a high calorie low nutrient diet and our inherited feeding traits have been found wanting. The food we consume now is not only higher in energy but, being less nourishing, it requires higher consumption to reach satiety. In other words, the negative feedback loop which once successfully limited our consumption is now compromised while our reward system’s positive feedback is still urging us to gorge, and this has led to addictive-like comfort eating. Psychological cues like boredom, perceived stress or negative mood may trigger persistent over-eating, even in the absence of hunger (so-called hedonic eating), as in Fig.11.

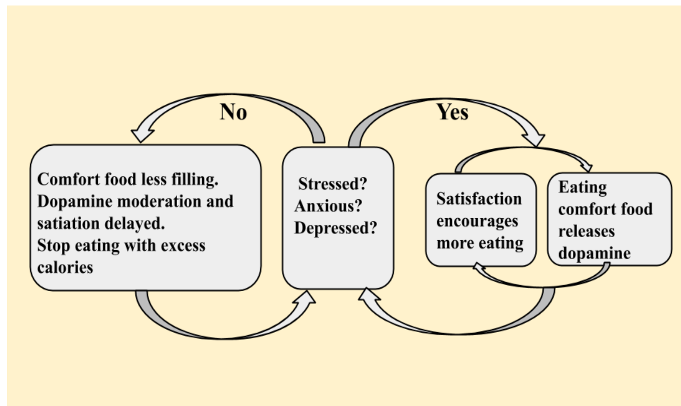
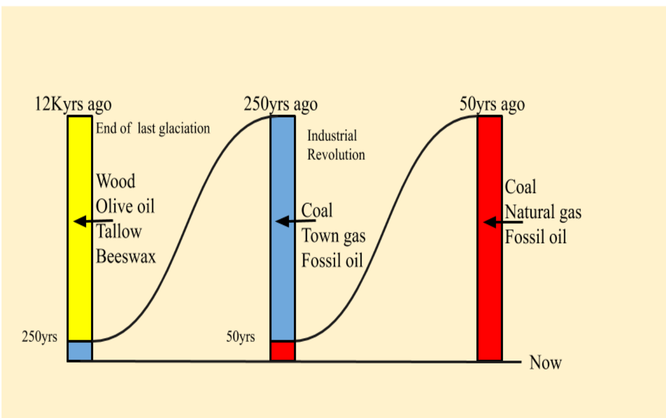


Fig. 11   Hedonic eating behaviour

With the set-point of the comfort eater’s negative feedback loops dictated not by hunger but mood the control of consumption has been further compromised, and has led inevitably to the obesity epidemic sweeping through the developed world.

Once obesity becomes established, overweight can no longer be countered by lifestyle modification (diet and exercise) and clinicians have now been advised that sustained obesity should be regarded as a treatment-resistant disease. Biological adaptations can then take place forcing maximum body weight to become biologically 'stamped in' and defended. Attempts to reduce body weight through diet will have only short term success because the individual has 'obesity in remission' and will inevitably return to obesity. Put another way, sustained obesity can reach a tipping point where irreversible structural changes result and a return to a healthy body weight is all but impossible, an insidious process which reveals its seriousness only after the tipping point has been passed, by which time it is too late to remedy.

For our planet the story is depressingly similar. To understand how instability manifests itself in our planet we start by examining the way humans have used fuels throughout the Holocene epoch, as shown in Fig.12.



Fig, 12 Timeline of human fuel consumption

Following the departure from the last Ice Age glaciation 12,000 years ago, our Homo Sapiens ancestors used wood as fuel for heating and cooking, with low-level use of coal for iron smelting, and olive oil for oil lamps or tallow or beeswax for candles. This lasted up until the start of the Industrial Revolution, about 250 years ago, when societies in the developed world satisfied their need for more energy by switching to fossil fuels, a process that has accelerated ever since, especially over the last 50 years.

As we emerged from the last of the Ice Age glaciations, Earth's atmospheric carbon dioxide level rose from around 180 ppm to around 280 ppm, mean surface temperature rose by about 4ºC and sea level rose around 100 metres. Then, throughout the pre-industrial Holocene that followed, our planet experienced only moderate or intermittent energy imbalances, and the temperature self-regulation system's negative feedback loops kept proper control. According to recent research, Earth re-established a stable climate with gently rising temperature, in good agreement with climate models[4]. This allowed the establishment of settlements, often in coastal or riverine regions, which developed into cities and eventually the civilisations we know today. None of this would have been possible but for the reliability of water supply, crop yields and sea level that came with a stable climate.

But when the Industrial Revolution brought with it a sudden surge in fossil fuel usage, atmospheric greenhouse gas concentrations rose and the temperature self-regulation started to struggle. It's cooling loops which utilise processes such as photosynthesis and chemical weathering proved too slow[5] to keep pace with the rapid warming, and the weakened negative feedback eventually lost its overall control.With the positive feedbacks still actively amplifying the warming, temperatures rose still further.

Today, our global energy consumption is more than 100-times that of our ancestors 500 years ago and still mostly derived by burning fossil fuels. We are now adding carbon dioxide to the atmosphere at an unprecedented rate and, with no significant overall control, temperature is free to rise unabated. The instrumental global temperature record (Fig. 13)

---

[4] Prior to this research, proxy reconstruction indicated a falling global mean temperature trend during the late Holocene, at odds with computer models. But the recent research concluded that the earlier reconstructions had misinterpreted the data and this realisation signaled the end of the so-called Holocene Temperature Conundrum.

[5] Looking ahead to Fig. 16, we see that in the Cenozoic era it took around 1 million years to cool by 2ºC, around 10,000 times slower than today's warming.

shows sporadic warming from naturally occurring events superimposed on a distinct rising temperature trend. If we maintain our current trajectory for greenhouse gas emissions the temperature rise will head towards ~4ºC. Even complying with the 2015 Paris Accord pledges will only restrict this to ~3ºC.

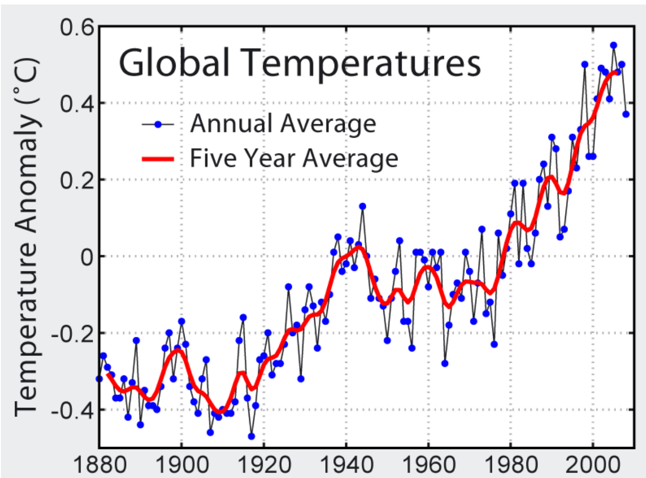


Fig. 13 Global temperature record (from [here](#))

So global heating has become established in our climate system. In 2020 global temperature reached [1.25ºC](#) above the 1850-1900 average, increasing at 0.18ºC /decade. The trend is already difficult to stop because, just as our bodies experience difficulty losing weight once obesity is established, our planet will also experience difficulty losing heat, even if emissions could be instantly stopped. The carbon dioxide already in the atmosphere will persist for centuries and continue to trap more heat. Should we be so foolish as to continue our bad fossil fuel habits, our bodies tell us what to expect: a future exposed to [climate tipping points](#).

Climate tipping points, such as those shown in Fig. 14, trigger largely irreversible changes to Earth's climate system,. Individually they have serious consequences but even more worrying is that above ~2ºC the climate could cross a planetary threshold beyond which tipping points may activate more tipping points in a [domino-like cascade](#), pushing Earth's system irreversibly to higher temperatures.

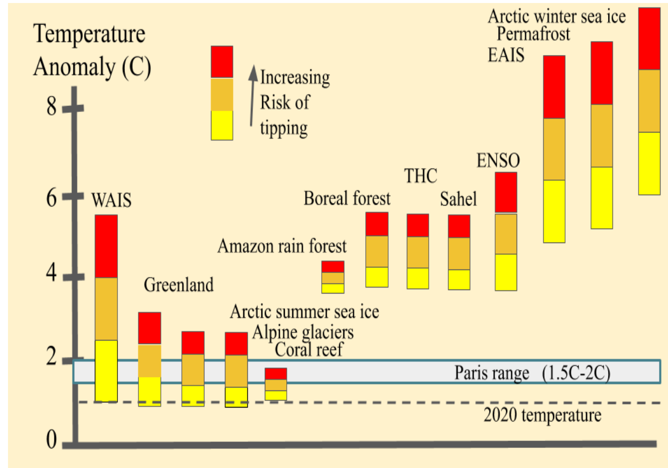


Fig. 14 Tipping points of Earth's climate system (taken from [here](#))

For example, the influx of freshwater to the North Atlantic by Greenland's melting ice sheet could slow the [Thermohaline Circulation](#) (THC) and destabilise the West African monsoon bringing drought to Africa's Sahel region or even dry the Amazon. Other potential tipping cascades are shown in Fig. 15.

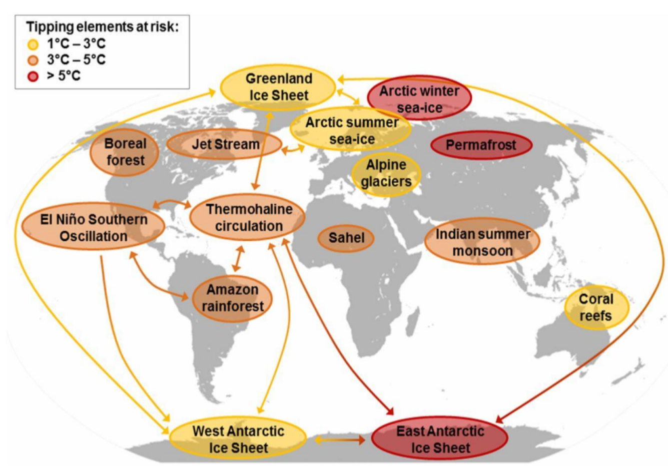


Fig. 15 Tipping cascades (taken from [here](#))

Just like the insidious process driving obesity, the seemingly benign heating that we are experiencing today has few warning signs of tipping points to come and when one reveals itself it may be too late to remedy. With perhaps 1 billion people living near sea level, the upheaval to civilisation would be unimaginable. What is uncertain is when such a tipping point might be reached. With greenhouse gases already leaking from the Arctic permafrost, some, including James Lovelock, think it already has.

Again our systems have demonstrated equivalence because they both:

- may lose control if their self-regulation's negative feedback is weakened by a large, rapid energy imbalance.
- are then pushed by positive feedback towards tipping points.
- are changed structurally once a tipping point has been passed, leaving them with no way to return.
- are already risking tipping points through over-consumption of junk energy, through processed food or fossil fuels

The dangers of taking liberties with our bodies or our living planet by allowing over-consumption of either junk food or junk fuel are clear: if an energy surplus occurs rapidly and is maintained it will sooner or later reach a tipping point where we will lose control and become locked into a dangerous downward spiral. By the time we realise the severity of the problem it will be too late to recover and then we can but sit and await the consequences.

Endgame: the downward spiral

Should we be so negligent as to allow tipping points to be passed, our complex systems will head towards and become locked into an altered state with no easy means of return. The new regime then in operation may unleash new positive feedbacks which force the system towards a terminal condition. With all hope of a return abandoned, all that remains, other than acceptance that the ultimate catastrophe is inevitable, is to adopt some sort of risky 'damage-limitation' intervention.

The obese individual is locked into a downward spiral of distress and binge eating, with food used more for emotional management than for satisfying hunger. Obesity can then conflate to morbid obesity with increased risk of diseased vital organs and reduced life expectancy. The morbidly obese individual may find activity increasingly troublesome and a sedentary lifestyle may head towards one of total inactivity. With increasing depression over an already poor quality of life, binge eating can become the mainstay. The vast intake of calories continues unabated while the energy expended is merely that of basal metabolism and the unfortunate individual's only recourse is with bariatric (weight loss) surgery. This intervention may be lifesaving but carries a serious risk of complications and requires a significant change of lifestyle afterwards. It's merely making the best of a bad situation.

With our planet's ice sheets disintegrating and temperatures still rising, more positive feedbacks may be activated, putting our future climate on a 'Hothouse Earth' pathway. For example, as the atmosphere heats, greenhouse gases may be released from drought-induced decay of vegetation and more frequent forest fires. This is the so-called carbon cycle feedback in which vegetation switches from being a carbon sink to a carbon source (a negative feedback becomes a positive feedback). As the oceans heat, stores of methane frozen on the seabed (in so-called clathrates) may be released, adding further to the greenhouse effect. The consequences of crossing climate thresholds is no idle threat: Earth's climate has been there before during the Cenozoic era, as indicated in Fig. 16. The rising temperature from 60 - 50 million years ago was the result of carbon dioxide released by the subduction of tectonic plates as 'India' drifted towards the Eurasia continent and the peak occurred when they collided, stopping the supply of carbon dioxide and producing the Himalayas in the process. The planet's mean temperature rose to more than 12ºC warmer than today but was then cooled by chemical weathering. Earth stayed ice-free for another 15 million years until the Antarctic ice sheet formed and a further 30 million years before ice sheets formed in the N. Hemisphere.

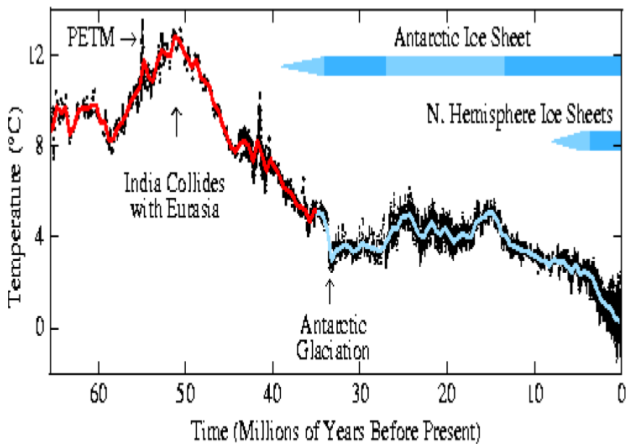


Fig. 16 Cenozoic deep ocean temperature reconstruction (taken from here)

Of particular interest is the Paleocene-Eocene temperature maximum (PETM) that occurred 55 million years ago and caused the temperature to jump 5ºC. It is thought to have occurred when it reached a tipping point causing the release of methane by the warming of methane hydrate frozen on the sea bed.

It is even possible to imagine that Earth could suffer the same fate as our neighbouring sister planet Venus. Of similar size and formed from the same interstellar gas as our own planet, Venus is believed to have suffered a runaway greenhouse, leaving its atmosphere today with 97% carbon dioxide and a temperature of 450ºC. Such an event, were it to happen on Earth, would herald the end of all life. So, should our present strategy of mitigation and adaptation prove inadequate and we find ourselves heading for such a disaster we may have to resort to a plan B. Just as bariatric surgery has been used as a surgical intervention for morbid obesity, geo-engineering is being considered as a climate intervention. Most schemes involve releasing radiation-reflecting particles into the stratosphere to increase the Earth's albedo[6]. However, the SCoPEx research project plans to use aerosols of calcium carbonate and has been criticised by some climate scientists who consider such technologies potentially dangerous, unpredictable and unmanageable. with possible risk to the ozone layer and the hydrologic cycle. It would also leave acidified oceans for centuries which would be disastrous for marine life. Furthermore, in view of the difficulties to secure a global agreement on how to mitigate climate change, why should we expect an agreement on global governance of the planet's thermostat to be any easier? Prevention was always better than cure, but one day climate geo-engineering might be all we have left.

Again our systems have demonstrated equivalence because they both:

- unleash further positive feedbacks after passing a tipping point.
- risk runaway decline leading to a terminal state, death of an individual or extinction of species.
- can recover only through intervention, using bariatric surgery or geo-engineering.

We must not stay with our 'business-as-usual' trajectory as this leads us to existential catastrophe for either our bodies or our living planet. Unless we change our bad habits our generation will be culpable and our grandchildren will have no one to

[6] These techniques replicate the effects of sulphur dioxide emissions from volcanic eruptions. For example, particles released from Mount Pinatubo in the Philippines in its 1991 eruption cooled global temperature by 0.6ºC for 15 months.

blame but ourselves. But what should we change and can our analogy help us choose?

Aftermath: avoiding catastrophe

The premise underlying this essay has been twofold: firstly, analogy with the human body should help us understand the workings of our planet and the dangers presented by man-made global heating; secondly, the instincts and good practices already developed for our own wellbeing might guide us towards a healthier future for our planet.

On the first point, we found that both our bodies and the biosphere have evolved self-regulating systems which protect their internal environments by stabilising around set-points vital for good health. Any surplus in either system's energy budget will be conserved within the system, making our bodies heavier or our planet hotter. Such surpluses (and deficits) have occurred naturally over the past 10,000 years and the self-regulation has worked well, but for the past few decades our over-consumption, both of calorie-dense junk food and carbon-dense fossil fuel, has created energy surpluses which have outpaced and overwhelmed each system's ability to respond. And if these surpluses are sustained there comes a time when the seemingly benign progressions of obesity and global heating reach tipping points where they become self-perpetuating and recovery is no longer possible. Should we reach those points, perhaps with the onset of co-morbid obesity or disintegration of the polar ice caps, we will no longer be in control. Then, with the energy budget still in surplus, new feedbacks may be unleashed risking terminal runaway, leading to death of the obese individual or mass extinction of all Earth's species.

On the second point, what lessons can be gleaned from our attempts to tackle the obesity epidemic and how can they help safeguard our climate? Here are some guidelines deduced using the analogy and which nicely complement the draft "climate manifesto" issued by Greenpeace in April 2019.

- *Trust the scientific consensus.* Our policies must be informed by the scientific evidence, rather than opinion, prejudice or ideology. When the experts agree and form a consensus individual human bias is reduced and the science becomes more reliable. There is now a consensus amongst medical professionals that to tackle obesity we must consume less 'free sugar'. Likewise, there is a consensus amongst climate scientists that to tackle global heating we must reduce, and eventually eliminate, our burning of fossil fuels.
- *Beware bogus 'experts'.* When money, ideology or power are at stake, truth can be conveniently sacrificed. Big Tobacco set the pattern when they intentionally misled the public about the health dangers of smoking and we can see similar tactics being used by Big Food and Drink and Big Oil, Coal and Gas. Coca Cola, the world's largest producer of sugary beverages, has recently teamed up with scientists and given financial support to a non-profit organisation to promote the idea that it is sedentary lifestyle and not their sugary drink that is the main cause of obesity. Likewise, ExxonMobil, the world's largest oil company, knew of the dangers of climate change as early as 1981 but spent $30 million on think tanks and researchers to promote climate denial for several more decades. We must not trust the myths created by industrially sponsored research.

- *Know the real cost.* Both obesity and global heating are very damaging and costly and if left unattended they will worsen still further. A 2014 [report from McKinsey and Co] reported that in 2012 worldwide obesity caused 2.8 million deaths and cost $2 trillion. Today, some 30% of the world's population are overweight or obese and this is expected to rise to 50% by 2030. Likewise, the International Monetary Fund has estimated that the worldwide cost of fossil fuel subsidies including the cost to society is $5.6 trillion p.a. while the 2007 Stern Review estimates that the cost of unabated global heating could eventually rise to as much as $16 trillion p.a. (20% of GDP). So, while junk food and fossil fuels may seem cheap we are actually paying more.
- *Stop bad habits while you can.* Granny was right:'a stitch in time saves nine' and 'prevention is better than cure'. Overweight can be rectified through lifestyle changes, namely diet and exercise, but once obesity has become sustained we may lose that option. Action to tackle global heating can't come too soon as we must already be dangerously close to irreversible disintegration of the ice caps.
- *Expect complications.* As well as the obvious disadvantages of excessive weight, obesity carries a high risk of health complications such as type 2 diabetes, heart disease and stroke. With global heating, there are climate complications such as destructive weather, aggravated resource conflicts and displaced populations, the so-called 'threat multipliers', with the biggest burden falling on the poor.
- *Curb the carbs.* The rapid transition from traditional foods, mostly grown in the community, to modern urban diets, especially sugary soft drinks and snacks, heavily marketed by multinational corporations, is a main driver of obesity. Likewise, with fossil fuels: hydrocarbons are to global heating what carbohydrates are to obesity, especially when they are refined and consumed with free abandon.
- *Avoid half-measures.* Piecemeal solutions to mitigate obesity and global heating will not work. Instead we need a bold, whole system approach involving scientists, business, government and civil society. There is no 'silver bullet' solution and solving the obesity epidemic will require changing our 'obesogenic' environment where fast food is ubiquitous and heavily marketed, larger portion and pack sizes are promoted, lifestyles are increasingly sedentary and catering convenience trumps nutritional value. Similarly with global heating, we need a holistic approach to break the fossil fuel industry's stranglehold and create a low carbon economy.
- *Make regulation independent.* We cannot rely on industry to regulate itself. Surveys have shown how ineffective self-regulation has been. In 2012, the UK food industry pledged to operate the voluntary public health responsibility deal but many firms have not complied and our eating habits are as bad as ever. The trade associations of the fossil fuel industry, like those for food and drink, continually rail against any sort of regulation that might impact their profits. Since the 2015 Paris climate agreement. the Oil and Gas Climate Initiative, intended to promote measures to mitigate climate change, spent $1bn on climate denial and lobbying while in 2019 alone the majors spent $115bn on oil and gas extraction.

Their fine words ring hollow and we need independent regulation of the industry.

- *Use taxation to regulate the markets* Free markets work effectively only on a level playing field. When junk food competes with nutritious food, such as fresh fruit and vegetables, it has a market advantage because its price does not include its social costs (health bills, absenteeism etc) which are paid by the general public, mainly through taxation. Likewise, the price of fossil fuel does not include its social cost (severe weather damage, migration etc) and this is making renewables (which have negligible social cost) look more expensive. One solution favoured by economists is to correct these market failures by imposing a 'sugar tax' to help counter obesity and a 'carbon tax' to steer us towards a low carbon future. These taxes would increase progressively each year until the required goal was reached, with the revenues returned to the public as lump sum rebates which, being neither regressive nor 'big state', makes the schemes politically viable.
- *Save the children.* Childhood obesity has become a major concern because it restricts their life chances and obese children will likely become obese adults. Global heating similarly will have its worst impact on children, especially those from poorer nations, because their underdeveloped immune systems will not cope with the extra disease and pollutants, and the damage will last their lifetime. Throughout history, the powerful have enslaved and colonised the weak to enrich themselves by stealing their human and material resources. We must stop the junk food and fossil fuel companies stealing the futures of our children and grandchildren.

All the suggestions above have shown strong equivalence between the two systems and it is difficult to find the flaw that analogies invariably have. Our planet and our bodies, though, have been framed throughout as two unrelated systems that just happen to have similar properties. So why might there be so many similarities? Perhaps their relationship would be better described as hierarchical. Just as our planet has been colonised by organisms (including humans) and plants which have co-evolved with our planet into numerous ecosystems (such as in forests or reefs), so have human bodies been colonised by bacteria and fungi which have co-evolved with our bodies into numerous ecosystems (such as in our gut or on our skin), the so-called human microbiome. Seen from this 'nesting-doll' perspective their similarities seem almost inevitable and we can be confident that our two systems, though totally different, are in fact fundamentally the same. Unfortunately, we can be similarly certain that, like many humans, our planet is becoming 'obese' and we are starting to witness the consequences.

Dr John Hughes *was a senior principal engineer with Philips Research at Redhill, Eindhoven and Silicon Valley and a Professorial Research Fellow at Imperial College, London University and Visiting Professor at Manakorn University, Bangkok He can be contacted at hugsallover@gmail.com*