Part 3 – The Life Sciences

Why did Man evolve so fast?

Sometime around seven million years ago, the evolutionary line for both humans and chimpanzees split and one cojoined branch eventually led to us. Those that separated to become chimpanzees have undergone relatively little change with the only notable point being the emergence of another chimpanzee variant: the bonobos. In the same period, giraffes grew a little taller, elephants gained longer trunks, horses hardly changed (until human intervention) and dogs and cats slowly spread into new landscapes, but otherwise barely altered form. Many other monkey and ape species, both solitary and those more social, simply became more specialist in their geographic and ecological environments – such as the forests of Madagascar or the jungles of Borneo. As for crocodiles, well, they've been large lizards forever, lurking around muddy rivers waiting for anything edible to pass by, unfussy about how evolved their prey might be.

Seven million years is a flash in the pan in the context of our genetic evolution on Earth. Over that time, a breed similar to today's chimpanzees evolved into humanity. It transmuted from swinging through trees to becoming bipedal, hairless, highly social beings with large brains and opposable thumbs, capable of complex speech and abstract thought, and which is now transforming the face of the planet and living in space. Comparing this transformation to that seen amongst other species of similar size over the same period, it's remarkable, to the point of being barely credible … unless you appreciate how it happened.

There is a concept promoted by some evolution theorists called 'punctuated equilibrium'. It suggests that species evolve in fits and bursts, between which there are long periods of relative stasis. The idea relies on the notion that large-scale environmental impacts take place such as ice ages, volcanic eruptions and so on, which transform the landscape, messing up the ecosystems, to which species have adapted, causing a re-adjustment and forcing the inhabitant species to change quickly over a short period to adapt to the new circumstances. And then everything settles down again in some form of new competitive equilibrium.

The ice ages of the Quaternary Period commenced around 2.5 million years ago. These did cause a drying in parts of Africa, turning dense jungles into forests. Certainly, there were also some major volcanic eruptions during the last 7 million years, which temporarily influenced the global climate for a few years or decades before the atmosphere cleared. But none of these impacts sufficiently affected the African ecosystems to shake up the gradual evolution experienced by many of those other larger creatures such as crocodiles, giraffes, elephants, chimpanzees, and so on, with whom we were figuratively rubbing shoulders.

Most species seem to have become highly specialised and only able to survive within those limited areas, to which they have become best adapted. In contrast, we became generalists and migrated around the world, having walked through some exceptionally hostile environments that would deter many a more sensible species. Ultimately, we learnt to live in a diverse range of landscapes all over the planet, which were completely alien to the warm jungles we grew up in. And now our numbers exceed eight billion where all these other species' populations are dwindling, unless, as per dogs, cats, sheep and chickens, they have piggy-backed on our success.

So, why did those other species undergo so little change, while we metamorphosed to such a huge degree in such a short time? The answer lies in understanding why and how members of species firstly compete and then learn to cooperate.

Chapter 16 - Nature raw in tooth and claw

Question - "If you were in the jungle and chased by a tiger, how could you best survive?"

Answer - "Outrun your best friend."

Let's go for a walk on a summer's morning along a footpath in the English countryside. On either side of you, displaying every shade of green, the hedgerows are bursting with life - varieties of trees, shrubs, blackberry bushes, stinging nettles and much more besides. Every plant is a vital system, seeking to survive and thrive. Each piece of greenery is waging a constant battle to find its own little bit of sunlight. Each has its own strategy. Some grow slowly, playing the long game. Others sprout upwards, expanding rapidly into any vacant space. Another set clamber up hosts, potentially throttling as they go. And yet others are throwing out tendrils to find new patches of fertile ground, their speed of growth almost perceptible from day-to-day. Then a rabbit scampers across the path, disappearing into the undergrowth, reminding of all the other living things hiding from immediate view - subterranean mammals, insects, molluscs, fungi and much more besides.

Nature is awesome. It is all the more so for someone trained in the physical sciences, for just as it is happening all around us, it is also something that we can't quite explain. Yes, we now know that all these plants contain a very complex molecule called chlorophyll in every cell in their leaves. This compound enables them to capture photons of sunlight and use the trapped energy to convert carbon dioxide into glucose. Simultaneously, all these trees and shrubs are extracting water and other nutrients from the soil, drawing them up their trunks to combine in their cells with those sugars to create the building blocks they need to grow. And how they grow. We have identified many of the chemical reactions essential for life. But we still haven't worked out what it is that drives all of this. At face value, it seems to contravene laws that we have otherwise deduced as applying to the material world - remember that drop of milk freely dispersing into a cup of black tea. And we now know that all those plants are indisputably constituted from the same atomic building blocks as both that cup of now cold tea and the very lifeless plastic chair you are sitting on.

All this exuberant life is dependent on its own basic construction part - the cell. Putting aside the conundrum of what vital force drives cells in the first place, we know that all that growth in the undergrowth happens because these cellular building blocks swell and replicate, multiplying to create larger and larger organisms. The cells in any living system cooperate together to create whole functional plant units, which as an identifiable entities compete against those others around, each stretching upwards and outwards to get a glimpse of sunlight. Each cell is a living system in its own right. But the eukaryotic cells, of which both we and plants are made, are now so dependent on cooperating together to create some larger system that they can no longer survive alone.

We can trace back through the geological records that precursors to these types of cells first came together to create multicellular life forms a few billion years ago. Before that, all life consisted only of single celled organisms, the ancestors to the bacteria, which we love (in our guts) and hate (in wrong places, such as a tooth infection). As puzzling, as not knowing what gives those cells their vital energy, is the question of why those original competing single celled systems were motivated to come together to become ever more cooperative, forging multicellular systems, such as all those plants, that rabbit skipping across the path in front of us and, of course, ourselves.

Winding back to the turn of the 19th century, the idea that we lived at the centre of a cosmic bubble had been thoroughly punctured. The Age of Enlightenment had progressed both practically and philosophically from that moment when Copernicus first glimpsed the solar system for what it is. The worldwide economy then circumnavigating the globe connected all major societies and, whilst some such as Japan were being reticent to join in, it was only a matter of time before their prejudices succumbed to the inevitable embrace of trade (Level 1 process). It was readily acknowledged by almost all that the world was a planet orbiting a star and had obviously been doing so for quite some time - certainly a great deal longer than the 6,000-year age of the universe inferred from the Bible. In intellectual circles, the notion that we were special in the eyes of a god was waning. And people were beginning to wonder what our true relationship was with nature.

Along came Darwin, who, having sailed around the world himself, presented his thesis on natural evolution. Victorian society, having moved on from the idea that species were immutable, had already been debating for a while how to categorise organisms and how such categories changed over time. And then suddenly, there it was, all set out in Darwin's book: *On the Origin of Species*. His ideas became mainstream at an unprecedented speed. It was the coup de grace to a world previously dictated by religious discourse (Level 3 influenced culture), leading to a more liberal, scientific and reductionist paradigm (Level 1 and 2 dominating cultures). His theory placed us as being a natural part and consequence of the emergence of life on our planet. And though many other aspects of our modern scientific edifice make us very ordinary, such as being made out of atoms and sharing very similar DNA with animals, it is Darwin's theory that nowadays attracts all the venom from the creationists, who remain unwilling to accept that we might not be the sacrosanct consequence of God's own personal design work.

Despite our subsequent discovery of genetics and the collection of immense amounts of data about living things, Darwin's core thesis - Survival of the Fittest - remains essentially intact. What follows neither challenges this nor contradicts his proposition that competition can drive species into environmental niches. But his theory is only a small part of the overall evolutionary story. Darwin's description of how nature works suffers the same type of quandary as that experienced by sociologists studying humanity. An observation that human beings are generally cooperative social animals doesn't help us understand what drives the progress of society, the consequential emergent social structures and the influences on human culture. Likewise, a recognition that generalised competition drives the development of species, without identifying distinct types of competition, gives only a very limited appreciation as to why and how genetic evolution works. It leaves life scientists only able to describe what they observe. It prevents them from formulating predictive theories or sweeping statements, as occurs in the physical sciences, such as all those laws and equations which students of thermodynamics must learn.

We now have the 'modern synthesis', which combines Darwin's Survival of the Fittest with our understanding of genetic inheritance. However, it remains a description of what's known to happen in the jungle, in your local woodland and in the soil underneath your lawn but is unable to fully explain why and how. The modern synthesis struggles to resolve shortcomings that were readily apparent to Darwin, such as the whys and wherefores of social insects. It cannot explain why some animals grow to a huge size, others fill the seas with myriad offspring, and lastly those rarities that develop greater intelligence. It certainly doesn't explain how we progressed from chimpanzee-like-creatures to ourselves in such short order. And it also fails to explain why we observe in the geological strata that whole ecosystems, and many species within, often last for long periods of inactivity and then experience sudden rapid change (punctuated equilibrium). The true processes behind evolution remain opaque, creating an opportunity for myths and misunderstandings to arise.

If you depended on watching David Attenborough documentaries to learn about ecology, then you would be forgiven for thinking that Survival of the Fittest is all about the predator-prey relationship. You can see on your TV screen the sleek power of a leopard sprinting after a daintily hopping gazelle and think that clearly the selective driver that has created the modern gazelle is the need to escape the leopard's jaw. To a degree it has. But not in the way portrayed by that film clip. For running alongside that gazelle, just outside the camera's focus, are other gazelles, also seeking to evade the big cat. From an evolutionary perspective, the real competition that is taking place on the savannah is not between leopard and gazelle, but between brother and sister antelopes. Out of these siblings, he or she who can run faster, will live another day, have off-spring and thereby pass on their genes. In this respect, the leopard is just context, an environmental hazard that all gazelles experience.

Leopards have a very varied diet, albeit all meat. They'll eat pretty much anything that moves which they can get their claws into. Consequently, the survival of that cat caught in the video clip is not solely going to hinge on the outcome of today's deer hunt. If unsuccessful, it's likely to find something else to munch later in the day. So, in an evolutionary sense, the leopard is not competing against the gazelle any more than you might be competing against the wild garlic that you pluck from the woodland floor. As per the gazelles, the leopard's real competitors are its brothers, who occupy the adjacent territories on the savannah.

Watching wildlife documentaries, it is easy to misconstrue that competition in an ecosystem is between species. The trap to fall into is to think that species are like teams - the leopard team, the gazelle team, the vulture team - all competing against each other. But this is absolutely the wrong viewpoint. A far better analogy is to imagine that a species, and the DNA that is passed on from one generation to the next, is like a cryptocurrency blockchain, where each organism, which successfully procreates and creates off-spring, represents a recognised transaction somehow embedded in the DNA, recorded into perpetuity for as long as the chain keeps going (see Box 16a). Competition in nature is between self-same organisms to contribute to a species' blockchain and thereby become recorded in history through that species' on-going DNA. But, as we'll explore now, there are a variety of ways to compete, including learning to cooperate.

Box 16a - Blockchains v DNA

Blockchain technology sits behind cryptocurrencies. It is a means to ensure that an accurate and un-editable record exists of a set of transactions or events. Clearly the way DNA is formed and operates is very different to blockchains. However, fundamentally DNA is a structure that holds information. Likewise, blockchains. The analogy being made here, and thereafter, is simply to make clear that the DNA of any individual organism is, essentially, a transaction record of all the ancestors that went before it - a record of all the successful evolutionary changes that have happened over time.

Darwin was wholly correct. The most direct competitors for a limited supply of a specific type of food, available within any ecosystem, are always going to be members of the same species (see Box 16b). This will give rise to the greatest level of evolutionary pressure, which as Darwin noted can drive a species into an environmental niche. By way of example, Darwin observed how differing finch species on adjacent islands on the Galapagos, which had obviously descended from the same original ancestors, had been driven by this type of competition to grow beaks of different lengths, which were specifically required to access the relevant food source on their native island. Simply, a new born finch, who had a better shape and length of beak to extract the main local source of nut, had a competitive advantage over its brothers and sisters and was more likely to pass on that trait to off-spring. In outcompeting its own brothers and sisters, it survived and reproduced, producing for each generation young which were evermore specialist, while the genetic lineage of those who were less honed to a particular food source died out. The outcome, as recorded in the *Origin of Species*, is that each island is now occupied by a different variant of finch.

Box 16b - Grey Squirrels v Red Squirrels

It's well known that grey squirrels have outnumbered red squirrels throughout British woodlands. Red and grey squirrels broadly eat the same food sources and are therefore direct competitors. However, grey squirrels have adapted to eat green acorns before they ripen. This means they can decimate the acorn resource before the red squirrels can access them. When population pressure causes food to be scarce, a major food source for the red squirrels is removed from the ecosystem before they get the chance to eat it. So, a key reason for the reds dying off is that they're simply starved out of existence by their grey cousins. It's not cats, not dogs, not kestrels that are killing off the red squirrels, but their nearest and dearest closest relatives.

In the last part, Maslow's hierarchy of human needs was introduced and then modified. Maslow originally developed his framework through the study of rhesus monkeys. It is, then, a simple step to realise that, if Maslow's hierarchy is relevant to human beings and if we are derived from the natural kingdom, his same construct must surely be relevant to other living organisms. Indeed, it is arguably applicable to every living system, from lowly microbes, including the cells of which your own body is composed, all the fungi under the woodland floor through to the great trees above, to all those autonomous living things, such as insects, chimpanzees, dolphins and ourselves. It was further suggested earlier that the intellectual attractiveness of Maslow's framework is the way that it fits our temporal experience - immediate, medium, and long-term needs.

Transposing Maslow's concept to the biological world provides a construct which treats all living things in first instance as energetic systems, which experience a set of priorities. Once in existence, to survive, every organism must, first and foremost, continually access and process energy from its environment. There are a few apparent exceptions, where some species are capable of entering periods of stasis, but even then they are relying on continuing internal processes drawing down built up energy stores (see Box 16c). More complex organisms, such as ourselves, use multiple sources of energy - including the air we breathe and the food we eat - which we combine to enable our bodies to function each and every second that we are alive. To press the point, for how long can you hold your breath?

Box 16c - Hibernating Trees

Deciduous trees clearly carry out photosynthesis only during the spring and summer months when their leaves are out. They effectively take a vacation from photosynthesising during the autumn and winter months. Photosynthesis uses the carbon dioxide from the air to build sugars and other essential material, which enable the tree to grow. Oxygen is a by-product. But trees don't just photosynthesise. They respire as well, just like we do, albeit they need less oxygen through respiration than they make from photosynthesis. Whilst a deciduous tree may seem dormant over the winter period, it continues to respire, burning up the sugars that it made during the last summer.

So, applying Maslow's hierarchy beyond the human domain provides an energetic hierarchy of processes, as follows:

1) Level 1 equates to the birth or inception of any identifiably independent organism (a separate energetic system) followed by the requirement to continually access and process energy. For multicellular systems, the activity of inception does not, however, cease after birth, it perpetuates as new cells are continually created to replace old (remember how you have a new pair of hands every few years).
2) Level 2 manifests as the need to secure an on-going supply of energy and to store energy, so as to survive any short periods of time when energy from the environment is unavailable (such as seasonal fluctuations). As will become apparent, this is expressed through the formation and growth of structure - after all, larger size allows for storage of more energy.
3) Level 3 transposes into the need for living things to maintain and regenerate themselves and to repair any structures formed through the Level 2 process.
4) Level 4 converts into the formation of senses and the gaining of autonomy - the ability to move about the physical environment with self-volition.

Reflecting to the temporal configuration of Maslow's hierarchy, these same processes are expressed in the life span of any organism. Having been conceived (Level 1), the next thing that all organisms must do is grow (Level 2). Logically, repair systems then only take effect once there is some structure to maintain (Level 3). Likewise, the ability of an organism to express autonomy (Level 4) is conditional on the prior creation of a self-repairing living structure. The needs hierarchy thereby simply transposes into an urgency of access to energy from the environment and the way energy is then used. That's all fairly simple and represents a rational step from the application of the needs hierarchy in a human context.

Treating organisms definitively as energetic systems allows cross-application of ideas between the physical and life sciences. Where biologists talk of ecological niches, physicists think in terms of qualities of energy, as will be explored in part 4. Food comes in a whole variety of qualities in the natural environment, say: squirrels eat nuts, where deer eat grass and moss, leopards eat deer. These foodstuffs represent alternative ways to obtain calories and nutrients - different sources or qualities of energy. Whilst the concept of the ecological niche, which is a core idea within modern evolutionary thinking, embraces much more than just source of energy, access to suitable calorie and nutrient sources is arguably the major component of any niche. Through an energetic lens, we can now refine further the forms of interaction introduced previously for the human domain (see Box 16d).

Box 16d – Forms of Energetic Interaction

We saw in part 2 that there are four identifiable ways in which a population can compete or cooperate for a limited supply of energy. This can now be further refined. It is easiest to visualise in the context of two agents, who need the same immediate food to survive – hence functioning at Level 1.

Passive Competition. This remains latent competition, where there no interaction takes place in physical space. If you imagine energy located at a precise point on a map, then this form of interaction represents one party arriving at the scene first, taking all the food and then departing. The other party then arrives and finds that the energy has been removed. The physical interaction, which they might have had, doesn't happen because of the temporal gap between them being at the same location.

Active Competition. This represents scenarios where they both arrive at the same point in space at the same time and therefore must fight for the energy – one wins, and one loses. It can also involve one having obtained the energy first and then bumping into the other and having the acquired food taken from them.

Active Cooperation. This involves one agent obtaining the food and then actively giving a proportion to the other. As per Active Competition, this is expressed as direct physical interaction in space. The reason why they might do this will be considered in the next chapter.

Passive Cooperation. This represents scenarios where the two agents swap quantitatively the same amounts of qualitatively different food. There is no net flow of energy between them. The exchange may involve direct physical interaction, but it is fleeting – effectively instantaneous. This could also be construed to be situations where one decides to eat something else, thereby reducing the perceived level of competition, which they each experience, and thereby avoiding any direct physical interaction.

The above examples all pertain to Level 1 Ideal Type interactions. There are equivalent forms for Levels 2, 3 and 4, which will become apparent through chapters 17 and 18.

Thinking of organisms as energetic systems is entirely consistent with Darwin's hypothesis, each competing against their closest brethren to live another day. But thinking of organisms as such does not resolve a rather fundamental question: if Darwin's approach sees the most intense competition taking place between organisms from the same species, why would cooperation between self-similar living systems ever emerge? Why do social insects form nests and hives? Why do lions form prides, dolphins pods, dogs packs and humans tribes? This focus on energy makes it even more apparent that organisms from the same species are inherently primary competitors for the same thing. The more successful a species is, the more intense that competition will likely be. But, somehow, cooperation does emerge? And, given how widespread it is, there must be a relatively simple answer.

What follows in the next few chapters represents a continuation of the thinking already set out for the social sciences. The insights derived in relation to the human system will be applied more widely, drawing on the same set of individual survival needs that have already been identified as the basis for the cooperation, which gives rise to the formation of structure and culture in society. But, as we are now going to explore, it is competition that ultimately drives the emergence of cooperation. That competition is, however, layered in the same way as cooperation appears to be in the human sphere. Competition and cooperation work together to create an evolutionary pathway, up which organisms can progress - referred to here as the cooperative ladder. It is not an easy route to follow. There are many distractions along the way that can send species down evolutionary dead-ends. This evolutionary route map could be likened to God's own game of snakes and ladders, as there's no certainty that a species will keep going up.

To understand how all this works, we need a case study. And what better example to use than the path that we ourselves have taken over the last fifty million years. Let's solve this ultimate life sciences conundrum - why and how does cooperation emerge between self-same energetic systems, which are intrinsically competitive entities?

Chapter 17 - Learning to live in a tribe

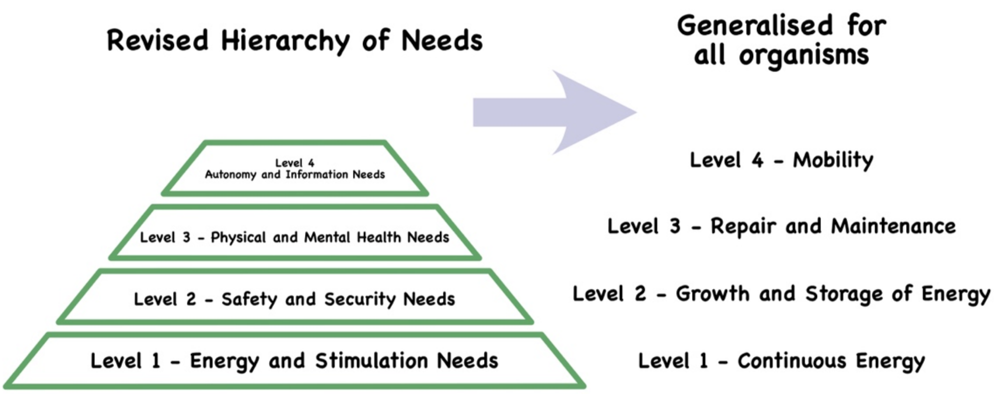
"Counter intuitively, cooperation is a response to intense competition."

A rodent-like creature scuttles across the forest floor and up a tree, heading for the canopy above to find some ripening berries. We find ourselves in the African jungles, a few million years after the demise of the dinosaurs. Mammals are emerging as the dominant land animals. The creature, we've just observed, has only recently learnt to climb. Its immediate ancestors were bound to the ground, dependent on fallen fruit and prone to heavy predation, especially by those dinosaurs. This constrained its population. But now this species has learnt to climb, and its numbers are flourishing. Over time its descendants become ever more physically adept at this new-found ability to escape up to and travel through the high branches.

Without having to worry so much about predators, the population of this newly evolved climbing rodent, swells to a level at which its numbers are now only limited by the amount of fruit in the jungle: in bumper years, more survive; in years of scarcity, the young and old die and numbers drop accordingly. The species, as a whole cohort of living organisms, frequently consumes all their preferred type of food available in this part of the jungle. In a thermodynamic sense, the population number tracks the energetic envelope, rising and falling according to calorific and nutrient availability in any one year. Competition for day-to-day energy between individuals becomes intense.

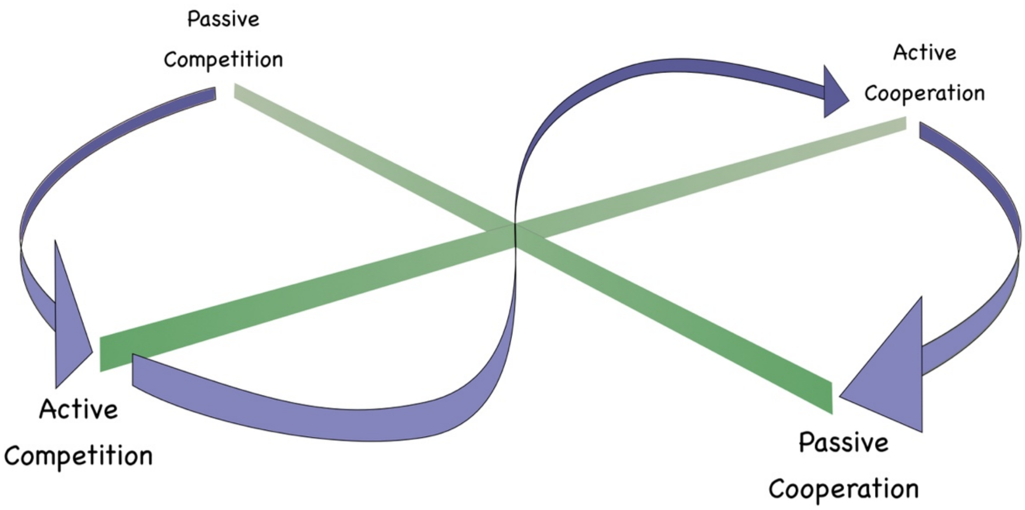
Applying the model so-far formulated for the human domain, there is a natural progression of survival strategies, which our rodents (soon-to-be-monkeys) can pursue. These courses of action are layered according to the priority of needs set out in the Revised Hierarchy of Needs (see Figure 17a), starting off with the rather essential matter of getting enough food to eat each day. The needs hierarchy effectively creates a cooperative ladder for our species to ascend, though the concept of steps to climb is a poor analogy. All strategies run concurrently. It is just that the lower-level ones take priority.

Figure 17a – Revised Hierarchy of Needs



As the species progresses up this cooperative ladder, there is a sequencing to the way they compete and then learn to cooperate at each level (see Figure 17b). Initially members of a species will tend to avoid being directly competitive through Passive Competition. This progresses into Active Competition, which can involve direct confrontation and conflict. Only when such Active Competition becomes sufficiently fierce will our species begin to explore the option of Active Cooperation, for reasons which will become apparent. Active Cooperation gives rise to social structures, within which continued pressure on resources causes evolutionary strategies to be explored through Passive Cooperation.

Figure 17b



Level 1 - getting today's lunch

Level 1 - Passive Competition. The initial competitive strategy is that deduced by Darwin, simply survival of the fittest for day-to-day energy. Those creatures who, through genetic mutations, are best biologically adapted to get to the fruit first are going to be more likely to survive, thrive and pass on their genes to a next generation. This is the process which leads to the finch with the longest beak or the giraffe with the longest neck. It harnesses random genetic mutations to select for physical specialisations. This form of competition is deemed passive. It is the equivalent of that person, who is the first to pick blackberries from the side of the footpath, denying the next passer-by from a snack. Organisms in a species are not actively competing (i.e. they are not stealing from each other) and thereby avoid direct conflict. Rather, they are just evolving to be the first and best able to get to and digest whatever food they specialise in. In the case of our climbing rodent, such adaptations could include a more acute sense of smell (detecting ripe fruit before others) or greater climbing agility (getting to the tree canopy first to pick the choicest fruit). Or, indeed, a combination of such physical refinements.

This latent competition causes the population to spread out across the landscape, seeking their preferred food sources. Some will end up moving into new territories and, in preference to conflict, try out alternative foods. Random mutations allow some to thrive in these neighbouring areas, giving rise to new variant species, dispersed spatially. By way of example, this gives rise to Darwin's differentiated finches on proximate islands in the Galapagos. But, within each location, this passive competition drives continuous improvement, specialising in accessing and digesting preferred food types (possibly only one type of food).

But Darwin's solution is, by definition, a repetitive zero-sum game of life (see Box 17a), which, when played out repeatedly, is self-limiting and leads to an equilibrium with a species in any single location no longer experiencing any significant further morphological changes. Out of any group of, say, early giraffes, the one with the longest neck will be able to eat the choicest acacia leaves. Her offspring are then born with longer necks. But having a long neck creates its own logistical challenges, such as pumping blood up to the brain. So other genetic mutations are required to facilitate any further accentuation of this adaptation. As time goes by and giraffe necks get longer, the difficulties mount, making it harder to be the most successful giraffe through having a longer neck. There may initially have been relatively rapid progress towards the giraffes we know now, with each generation being noticeably taller. But eventually that specialisation slows down with the species effectively becoming stuck in a metaphorical evolutionary rut - they compete to have longer necks, but, for so long as their environment does not fundamentally change and they continue to feed off acacia trees, having a longer neck doesn't in the round benefit any individual and doesn't make it more likely to breed successfully. In summary, the longer neck strategy experiences diminishing returns. A competitive equilibrium is achieved allowing for little further change.

Box 17a - Zero Sum Games

Within mathematical game theory, zero sum games are those where the amount gained by a winner is the same as the loss experienced by a loser. Poker and many forms of gambling are zero sum games, where the winnings for one party add up to the same total as the losses of the other(s). In absence of any consequences, such as in an environment of poor law enforcement, then stealing is also a zero-sum game - the robber's material takings are quantitatively the same as the victim's losses.

When a zero-sum game is repeated over and over, with an even statistical chance of one or other winning, it can lead to an equilibrium situation where ultimately there is no strategy (i.e. finding a perfect physical form) which can beat all others.

Level 1 - Active Competition. Trees providing a suitable source of food are scattered throughout the jungle. Fruit ripens in each location on an intermittent basis. Our hungry climbing rodents are desperate for something to eat. Perhaps last year there was a bumper crop of fruit and this year not so much, so food is scarce. Now, they each might be lucky and chance across some ripening fruit before it's found by others. But relying on their own senses is always going to be quite hit-and-miss.

So, an equally effective strategy is to listen and watch carefully for their peers, because for sure wherever there is a group of others, then that will be because of food. When the fruit on a tree becomes edible, our early squirrel-look-alikes rush in from all directions to gauge themselves on juicy berries - an intense mass of squawking, screeching creatures scrambling to get to the fruit first. It is everyone for themselves - take your fill and move on. There is no coherence to this population. They don't flock, as such. When fruit has been consumed in any one tree, they all head off in different directions, looking for more fruit (see Box 17b).

Box 17b - Seagulls

Seagulls follow active competition. They fly around independently scanning for food. The best way to identify if there is any food anywhere is to spot a gathering of other seagulls. Hence, as soon as there are two or more seagulls in any one location, suddenly there are lots, all pouring in to catch some bread. Any who do get a morsel of food are then harassed by their fellows. Once the food is all eaten, they disperse away, scanning the horizon again, hoping to luck out and grab some food for themselves but failing that spying the next gaggle of seagulls to join.

Now, put yourself in the figurative shoes of an early rodent, espying others of your own species heading for a fruit tree. You quickly join the throng, to get some food before it's all gone. When you arrive, an obvious strategy to pursue is to become an aggressor. If you scare others enough and make them fear for their lives, they'll back off and you can take your pick of berries. So, one climbing rodent becomes more assertive and eats fruit, potentially even stealing from another, while that other loses out and goes hungry - a win today for the aggressor. But as an evolutionary strategy, this also inevitably leads to an equilibrium. The more aggressive squirrel procreates, where the non-aggressive one does not. The next generation, and each one after that, are successively more threatening to their peers, until they reach an equilibrium whereby being more aggressive is no longer better because it leads to fights and injuries. Being injured is bad news for survival and propagation. As aggression can only ever be taken so far, played out over and over again, it is also a repetitive zero-sum game.

Level 1 - Active Cooperation. So, when everyone else is specialising or fiercely competing, what advantage could there possibly be of cooperating?

To comprehend why any individual organisms might follow a path of active cooperation, one first must appreciate that all food comes in quanta - that is defined lumps. The luscious produce in the tree canopy is not a continuous supply of energy, rather it exists in the form of individual fruits. Now, let’s consider what happens when a crowd of climbing rodents ascend a loaded tree. Imagine there are one hundred creatures and ninety fruits. In this scenario, ninety get to eat and ten will go without. If the food supply were continuous, then everyone would simply get nine-tenths of the amount. But the fruit doesn’t come like that. Competitive animals take one each and eat the whole thing. Those that go without may well perish (or at least be severely weakened) before they can get to another tree.

Being an aggressor, seeking to scare off fellows, takes more energy than being peaceful. It takes effort to stand your ground (hold onto your branch?) and then warily munch a succulent fruit, worried that another might steal it off you. So, while some of the monkeys are waving their arms around, screeching threateningly, others can slip onto the other side of the tree, forage some fruit (albeit less than one each) and, if need be, scamper off with it. Through sharing the fruit, this small pack of more peaceful creatures can turn a lumpy supply into a continuous flow of energy. They may get less than a whole fruit each, but being peaceful they need less energy anyway, and a fraction is better than nothing. It keeps you going for an extra day, until another tree nearby comes into fruit. The most obvious way, in which this new behaviour emerges, is where a mother continues sharing with her young well beyond the time that others would have sent them off to fend for themselves.

This cooperative approach may seem to have limited benefit on one occasion. But if the rodent population is continually bumping up against that energy envelope, then being peaceful gradually becomes a successful long-term game strategy. These peaceful climbing rodents will wander around the forest as a loose group - a bit like a herd (see Box 17c). This Level 1 sharing is entirely opportunistic - they will each only do so when required and, if another has their back turned, they won't pause to devour what they can. So, to be assured of getting a share, they all need to stick together and monitor each other. But each of these animals is still an individual entity with its own needs. Its innate competitiveness has not been instantly turned off. Rather inherent competition now becomes internalised within the group. The prior degrees of aggression become muted and manifest in the form of leaders and followers.

Box 17c - Herbivorous Herd Animals

Surely the grasses on the savannah represent a continuous supply of energy?

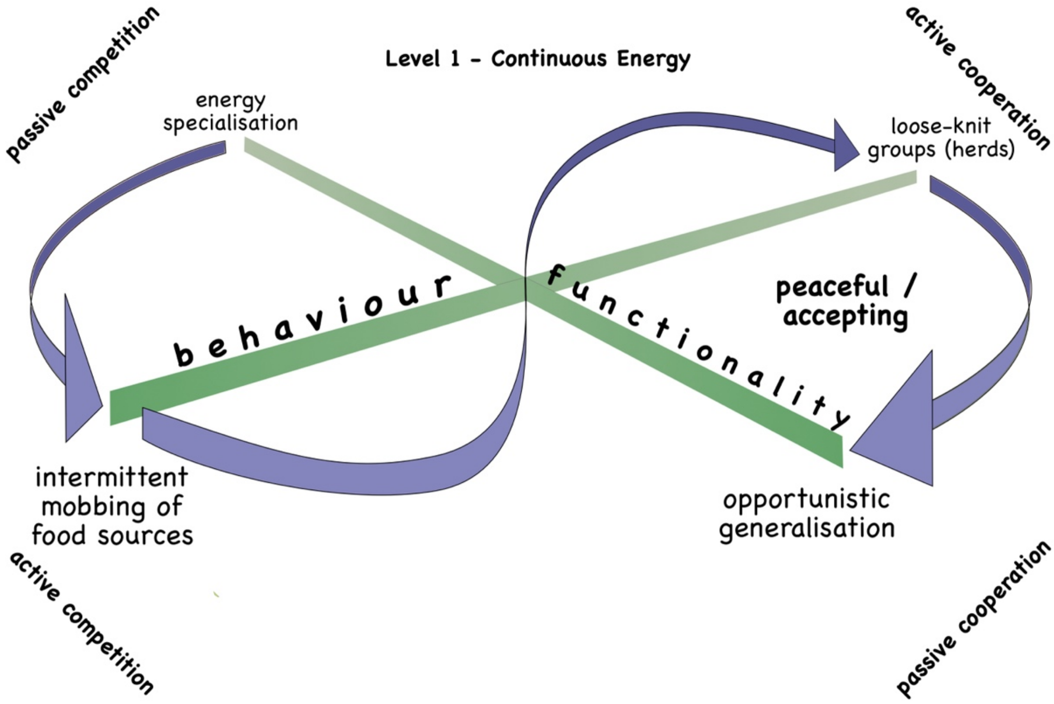
Indeed, most years, the bison, the antelope and the zebra can all munch away on a plentiful pasture. And, likewise, drink their fill from freely running rivers. But, in those years when the rains don't come, then even the grasses and the water supply retract back to small clumps or puddles. It is those years of famine that become critical filters on who survives to pass on their genes. Even these grazing mammals are forced to learn to be peaceful to share a limited supply of food that is available in discrete lumps. And, so, they wander around in loosely grouped peaceful herds, sharing wherever they go.

Level 1 - Passive cooperation. Continued competition for food drives some of our rodents to try different food sources. In a population of individual competitors, this would have led to diversification and the potential emergence of a new specialist species. But now that these organisms are traipsing around the jungle as a coherent group, such tendency for divergence becomes assimilated. The outcome is that they begin to become generalists, snacking on a much wider array of food types, following a path towards opportunistic omnivorousness (i.e. they will have a preferred food type, but will snack on other things when hungry). Any mutations, which enable an individual to better digest these other food types, will be absorbed into the group and thence the species. Becoming omnivorous enables the species to access a much wider diversity of food types and thence energy sources from the landscape, creating the possibility for progression towards groups becoming established in fixed locations.

Cooperative Ladder

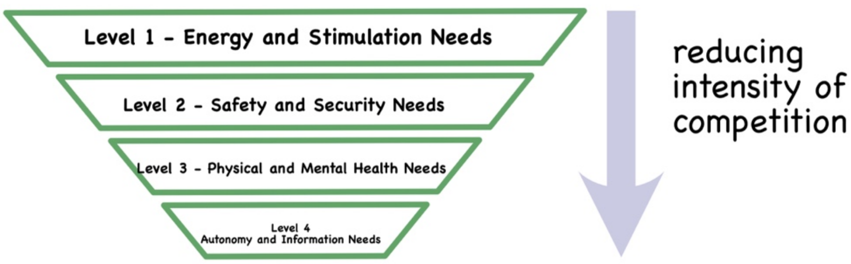
These then are the four Level 1 game strategies that can be followed by the organisms within a species, which will be tried out in a particular order (passive competition through to passive cooperation) (see Figure 17c) and are played out over the course of time, leading to winners and losers. The winners pass on their DNA and so the species evolves - the DNA being a record of what has proven to be successful. It can be seen from this that passive competition (becoming more specialist) and passive cooperation (becoming more generalist) represent diametrically opposed strategies, lying on a spectrum from one extreme to the other. These give rise to functional changes in terms of how the organisms interact with their environment and process the energy and nutrients they can find. Likewise, active competition (aggression) and active cooperation (peacefulness) are the antithesis of each other. These represent behavioural changes.

Figure 17c – Level 1 - Interaction Sequence



For those early climbing rodents that follow strictly competitive pathways at Level 1, they can become stuck in an evolutionary rut, unable to progress further. They remain a population of individuals. The survival of the fittest competition, played out between self-same creatures, drives the species either into a narrower role within the ecosystem and/or to become increasingly aggressive towards others of their own kind. Organisms within the species will continue to compete individually at all higher levels, albeit to reducing levels of intensity (see Figure 17d).

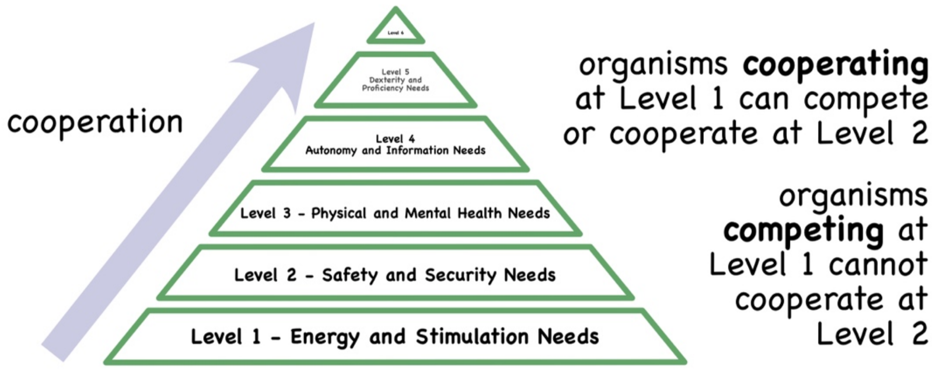
Figure 17d - individual competition - reducing intensity up levels



Cooperation, when it happens, starts at the bottom of the ladder and progresses upwards (see

Figure 17e). Members of a species, who have learnt to cooperate at Level 1, may still compete individually at Level 2. The reverse cannot happen. Members of a species cannot compete as individuals at Level 1 but cooperate at Level 2 – in the human domain, you can't cooperate with another in defence of your town while stealing food from them.

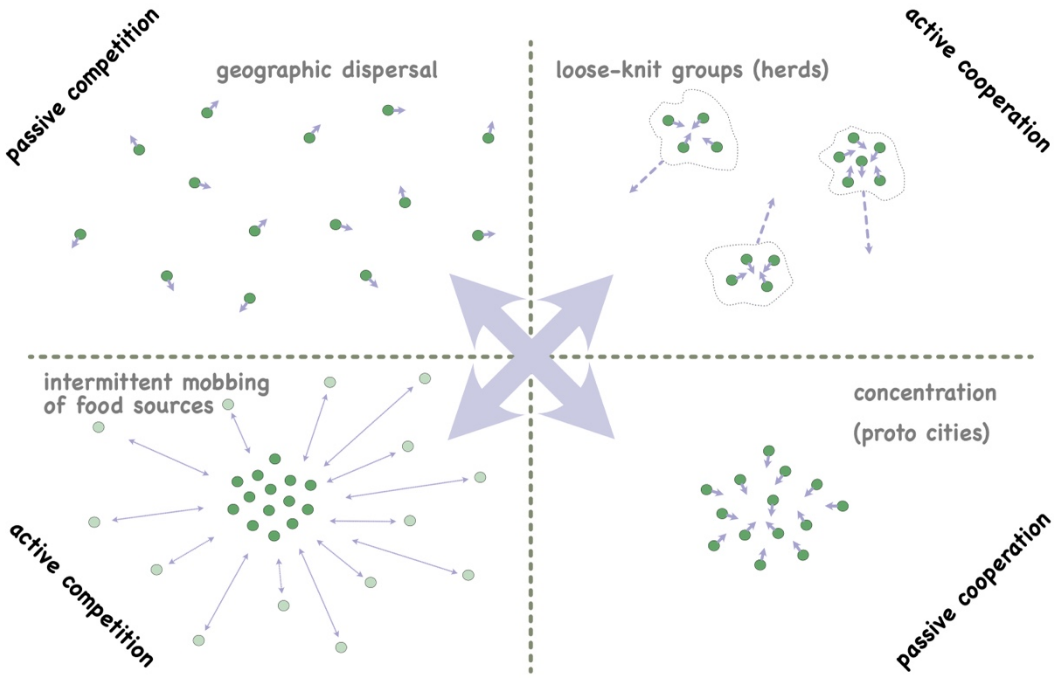
Figure 17e - cooperative ladder



Level	➔ progression up cooperative ladder ➔				
1	competition	cooperation	cooperation	cooperation	cooperation
2	competition	competition	cooperation	cooperation	cooperation
3	competition	competition	competition	cooperation	cooperation
4	competition	competition	competition	competition	cooperation

For those species that start to cooperate and form groups at Level 1, then the nature of the competition experienced between organisms obviously changes. It is now the newly formed groups, which are competing as units for food on the landscape. This represents a symmetry break in how the population functions in the physical environment (see Figure 17f). When this group behaviour has become established, it is no longer tenable for individuals to function outside of any group – cooperation essentially becomes forced. Within each group, there continues to be latent competition between members, but this transforms from direct physical, very real confrontation (i.e. taking food off each other) to becoming virtual, such as trying to lead the group. With Level 1 competition now effectively tamed, the primary form of competition between members of the group moves up to the next step on the cooperative ladder.

Figure 17f – geographic distribution of population



Level 2 - withstanding a missed dinner

Moving up to the next level, we see the same four potential strategies repeated, albeit expressed differently. As the food supply is smoothed (no longer quantised), this opens new opportunities for individuals to get a competitive or cooperative edge.

Level 2 - Passive Competition. The Level 2 equivalent of energy specialisation is to become more energy efficient - to become leaner and keener (and possibly smaller). This is not possible when energy supply is lumpy. But once continuous, those creatures who can evolve to do more with less will experience an advantage over their peers. This is another type of physical adaptation. Like other competitive strategies, this is a zero-sum game, leading to evolutionary equilibrium. This sub-species is now even better adapted to, but simultaneously more reliant on, a singular food source. As individuals within a group become more efficient, each eating less, the size of their group may grow in number.

Level 2 - Active competition. Whether Level 2 active competition is between single organisms or cooperative groups, this type of competition manifests as territoriality.

When competing at Level 1, gaps between each instance of feeding causes our climbing rodents to use up energy as quickly as they consume it. Mutations leading to faster-growing or larger individuals are filtered out. But when, through sharing and/or generalising food sources, the energy supply becomes steadier, there becomes scope for individuals to start competing within the group by growing larger. Simply put, any mutations that result in an increase in growth rate or final size will confer greater success. Size has a key advantage in that it allows for more energy storage, which gives a greater chance of survival during predictable periods of dearth – surviving the winter, perhaps.

The Level 1 cooperative group operates as a coherent unit, where individuals recognise each other within the group but are hostile to those outside. As competition between whole groups intensifies, they increasingly fix themselves to and defend a single area, trying to scare off any other competing groups from, what they see as, their trees. Locating themselves in a specific area makes it easier for members of a group to stay together and reduces conflict from accidentally bumping into other units.

Together they must defend their territory. But there is no trust between them. It is, therefore, the leaders who bear the brunt of responsibility for threatening away intruders, the success of which depends on their own size and aggressiveness. What was a relatively informal ranking in the Level 1 group now converts into a strict permanent hierarchy (see Box 17d). The rest of the group lines up behind the leader, seeking to ward off competitors through sheer numbers, where the size of the group is itself dependent on the size of the leader. When conflict does occur, then the smaller and less aggressive ones pull away, hoping that their leader will win the fight for them. Or they might even try to change sides. As the amount of food available derives from the size of the area, so a larger group will need to expand its territory. But, as they need to stick together to share, there's only so much area they can practically defend before they likely splinter into two groups.

Box 17d - Chimpanzees

Our chimpanzee cousins operate as Level 2 actively competing groups. They form highly hierarchical membership groups which occupy a very specific territory. Any individual, especially males, who wander outside of their troop's territory, is liable to be killed by neighbouring groups. There is, therefore, no cheating this territorial system. Male chimpanzees are stuck with their troop for life, no matter how well they get on with their brothers.

Those at the top of the hierarchy are rewarded for their exertions by getting first choice of food and ruling the roost for the rest of the time and all the others must pander to their whims. This contributes to reproductive success of the leaders, causing generation-on-generation growth. But leadership is not an easy place to stay. It is a very stressful position to hold, keeping others in the group at bay and having, essentially single-handedly, to defend the territory. As the individuals have limited lifespans, this system is inherently unstable, with territories expanding and contracting according to the size and aggression levels of current leaders. The outcome is that there are perpetual border squabbles between neighbouring groups, with territories always trying to expand but intermittently contracting or being taken over.

The combination of factors gives rise to competitive growth. This leads to our originating rodents enlarging rapidly from generation to generation to become, say, monkey-sized. Growing larger is, of course, a zero-sum game, leading to evolutionary equilibrium - much like the neck lengthening strategy of the giraffe. If there is a fixed energy envelope for our species, then for every animal that puts on some weight, another is looking a little skinnier and withers away. When competition drives them to grow, then there will consequently be a lower population of the whole species, albeit same total biomass (see Box 17e). (The biomass of a species is the total body weight of its whole population.)

Box 17e - Why did the dinosaurs grow so large?

The large herbivore dinosaurs, such as the Diplodocus or the Brontosaurus, are generally envisaged as having wandered around the landscape in herds, which were most likely hierarchical in the same way that horses are very hierarchic. The dinosaurs had mastered cooperation at Level 1. This meant that they could now compete at Level 2. Over long epochs of time, this competitive growth caused them to swell hugely in size. Their functional form underwent little change. They just got larger, albeit there were various mutations required to enable size to be successful, such as having lighter bones. Such competitive growth would have experienced the same diminishing returns as giraffe necks. The reason why they ultimately grew so large was because they spent so many millions of years experiencing competitive growth.

Level 2 - Active Cooperation. Is there a strategy that some can follow, which will enable them to out-compete these very hierarchic troops, which are constantly trying to grow their territories? Indeed, there is.

If the individuals within a troop can become more trustworthy (behavioural change), then they gain the ability to operate as a more coherent unit to defend their territory. Where before the smaller and weaker members of the group ran away at the first sign of serious aggression, in a troop learning to cooperate, they predictably all hold the territorial line together. They depend on each other to stand firm in the face of outside threat and, if required, for all of them to participate in the fight. If most of the opposition runs away at the first sign of a battle starting, leaving only that other leader, then this more trusting group have a better chance at winning. This development of trust depends, however, on some concomitant behavioural changes within the group.

Firstly, for them all to stand firm together, they need to be a more standard size. This requires there to be a more equal distribution of food amongst them, such that those at the top of the hierarchy do not get a disproportionate amount. The result of this is that they largely forego competitive growth. Secondly, there need to be ground rules, which they all follow. It would no longer be acceptable, for instance, for one higher up the hierarchy to attack a junior member of the group without consequence. For trust to flourish, all members of the group need to feel safe together and not living in fear of their own leader.

When these factors come together, then a troop of monkeys gains a competitive edge in holding and defending a territory in the jungle. The number in the group is now defined not by size of their leader but by level of trust. If the group grows too large, it is still likely to splinter. Consequently, not only do members of the group no longer compete between them to grow larger, but the group self-limits its size.

The logical conclusion of this process is that the group becomes completely egalitarian. But the more likely scenario is that a degree of hierarchy remains, operating according to culturally adopted rules and codes of conduct to limit the degree of aggression, which can be expressed by any leaders. In this regard, the very real hierarchy in actively competing troops becomes tamed and life for all members of the group improves (see Box 17f).

Box 17f - Capuchin Monkeys and Bonobos

Capuchins are South American monkeys. They are one of the most intelligent and are known to use tools. Capuchins live in social groups of up to 30 individuals, which occupy defended territories. Whilst their groups are normally hierarchic, there are some examples where this does not seem to be the case or is relatively minimal. Furthermore, they are known to punish members of the group who help themselves to a deemed unfair amount of food.

Bonobos have progressed beyond the aggressive world of steeply hierarchical chimpanzee troops. Instead of a male hierarchy based on physical size and level of aggression, they exhibit a female hierarchy and function in a far more egalitarian manner.

Level 2 - Passive Cooperation. Now that the group occupies a well-defined territory with a limited availability of food, erstwhile opportunistic omnivorousness becomes formalised and members of the group are forced to become increasingly dependent on a wider variety of food stuffs. Eventually they can no longer exist only on their originally preferred singular food type (such as fruit) and must consume a range of foodstuffs to satisfy their nutrient requirements.

Level 3 - maintaining good health and successful reproduction

Next rung up the ladder, we see again the same four alternative paths for members of our now early monkey species to take. We move on from Level 1 (trying to get today's meal) and Level 2 (securing an on-going energy supply) to how best to maintain good health and how to reproduce successfully. (We will return later to explain the intimate link between health and reproduction.) Whilst our climbing, fruit-loving furry friends now form groups willing to stand together to defend their parcel of the jungle, inside the group it is still the individual perspective that is important - each organism has its own survival needs and is the means by which a record of success can be passed onto future generations.

Level 3 - Passive Competition. Our early monkeys at Level 3 look after themselves health-wise and spend considerable time and effort rearing their own progeny. There is no mutual healthcare between members of the group. Parents only have a few offspring, often one at a time, and they focus on making sure that these survive to the point of being able to look after themselves with every likelihood of successful future reproduction. This means that there is significant temporal overlap between generations, which creates a dilemma. Within the bounds of the troop's territory, it means that there is competition between old and young for the same limited supply of energy. This severely limits the population size and churn, so that the species becomes slow to adapt to changing circumstances. Yet each newly born has a high statistical chance of survival and procreation (see Box 17g).

Box 17g - Herd Offspring

An obvious natural example of this type of behaviour are those various grazing species on the savannah, such as gazelle and zebras. Whilst the young are seemingly absorbed into the herd, in practice it is the sole responsibility of the mother to rear her own offspring with little, if any, help from others in the group. Note that this is not the case for all herd animals.

Many species in the insect world have found an interesting solution to this intergenerational competition. The young and adults have become differentiated to survive on different food stuffs. The classic example is the caterpillar and butterfly: one eating greenery, the other drinking nectar. This represents diversification of physical form within the species, rather than creating new species, as happens from such competition at Level 1.

Level 3 - Active competition. Whether functioning in a group or not, active competition at Level 3 manifests as maximisation of offspring. This can be expressed either through increasing rate of reproduction or producing large numbers of progeny. This is clearly energy intensive. It is again a zero-sum game eventually leading to an evolutionary equilibrium. The more offspring that are produced, the less nurture can be given to each one. And, within the limited energy availability within the group's territory, the more young they produce, the smaller those young will be and the chances of survival of any one reduces. It becomes a statistical game. As everyone else produces more and more young, the whole process becomes self-limiting. This type of competition leads to massive booms and busts of the population (see Box 17h).

Box 17h - Birds (passive competition) versus Fish (active competition)

Birds and larger land animals, which live alone, tend to focus on Passive Competition, intensive self-nurture and rearing of young. Rats and other smaller mammals seem to be more actively competitive at Level 3 and they consequently tend to produce huge booms and busts in population numbers. In the oceans, Active Competition is taken to extreme lengths (in much the same way that dinosaurs took competitive growth to its logical conclusion).

Whereas birds are able to make nests that are relatively safe from predation and thereby focus on just a few young, presumably in the oceans seeking to protect a brood of eggs is much more challenging. So many sea creatures don't bother trying. Instead, many fish species have evolved to produce hundreds of thousands, sometimes millions, of eggs per fish when they spawn, where only a minute fraction of these eggs will ever survive and mature to new adult fish. With so many new offspring created, there are greater opportunities for genetic mutations to arise, making the species as a whole able to adapt faster to a changing environmental context. This, perhaps, explains why fish species respond quickly to overfishing by reaching sexual maturity quicker and adult fish becoming smaller.

Within our troop of monkeys, this Level 3 competition gives rise to a social layering. Where there is already a hierarchic structure, then this layering simply maps onto what already exists, such that those higher up the social system gain preferential reproductive status - another benefit accrued to those stressed-out leaders, defending their territory. Position in the system, whether hierarchy or layered, defines who grooms who and who can reproduce with who: those lower down are expected to do more than their elevated peers. Offspring gain the benefits or disadvantages of their parent's status, so not all the offspring gain the same level of nurture - some are highly valued, others treated like runts. Further than that, there may exist infanticide, where higher status monkeys actively kill the infants of their lower ranking peers. This internal competition limits the reproductive success of the whole group.

Level 3 - Active Cooperation. Where a strict, merciless hierarchy still exists (Level 2 Active Competition), then cooperation at Level 3 is impossible. But, once a group has learnt to cooperate at Level 2, then this opens the scope for them to help each other more in relation to health and reproduction matters.

To advance to Level 3 cooperation, they need to lose the status system and move to a situation where every monkey gives as much as it receives when it comes to removing tics from each other's backs or looking after each other's offspring. The outcome is that the troop formally converts into a community, where the cycling of reciprocal assistance goes round the whole troop, equitably. Where, in a Level 3 actively competing troop, the survival of a youngsters is entirely dependent on the on-going health of his own mother, this is no longer the case. In the community, every member of the group (to varying degrees) participates in ensuring the success of each new infant and the reproductive success of the whole group improves.

As with Level 2 Active Cooperation, there are some further cultural changes required to enable this to happen. It is important for individuals to cease competing reproductively. This helps to stabilised troop numbers, which are less likely to go through booms and busts. This is likely to be accompanied by cultural behaviours within the group, which either control or take away the need to compete sexually. This is evident within bonobos, those more gentle cousins of the chimpanzees (see Box 17i). Also, as before, the innate Level 3 competition between individuals becomes tamed. This requires a bit more explanation, which will be returned to in chapter 21.

Box 17i - The Bonobos

The bonobos are an obvious example of a species that has fully reached Level 3 active cooperation. The bonobos have grasped the need for reciprocation and to be reliable towards each other. This has evolved into a variety of, what seem to be, sexual rituals, seeking to re-assure each other of their mutual reliability and willingness to give each other care and attention. Bonobos share the effort of nurturing off-spring across the whole troop, even the males participating, to a far greater extent than seen with chimpanzees. In contrast, female chimpanzees are reproductively competitive and known to kill the offspring of unrelated chimpanzees within their troop, with male chimpanzees offering little assistance to rearing their children.

Level 3 - Passive Cooperation. This leads to further generalisation in the species, which goes well beyond eating habits. We'll also return to look at this in detail in chapter 21.

Launchpad to Level 4

It was a long, slow process evolving from original population of climbing rodents to troops of reproductively cooperative primates. Whilst the environment played an influencing role, such as them becoming ever-more adept at climbing trees, the strongest motivating factor, which drove this evolution, was internal competition within the species - brothers and sisters competing against each other. Darwin observed and documented how evolutionary competition drove physical changes in species to become ever more specialised. This can be readily seen in the geological record, as fossils can be documented in rising strata gradually evolving from one form to another. The emergence of cooperation tends to be either a behavioural change or a functional change, such as becoming less aggressive or more omnivorous. Neither of these are readily apparent from analysing the fossil record. So, Darwin's hypothesis was automatically limited to a small part of a much bigger story.

Learning to share represented a means to smooth the supply of food available for individuals. It is an adaptation, which is driven by intense competition for the same food by a population of self-same energetic systems. It only makes sense when it is appreciated that food comes in the form of quanta, whether that be one apple on the tree, one shrub in the desert or one gazelle on the prairie. It is as simple as that. And, with sharing, our ancestors took the first step up the cooperative ladder. This led to the formation of outwardly competing groups, where Level 1 active competition between individuals turned into Level 1 active competition between groups. Functioning in groups drove self-same organisms to live more intensely together. And within those intensified social environments, they competed and then cooperated in increasingly sophisticated ways, transforming themselves over time.

So, that's Levels 1 to 3 of the cooperative ladder (summarised in Figures 17c (above) and 17g and 17h (below)), transitioning from a species which reproduced as individuals to one which was reliant on living in close-knit groups, which could defend territory containing a source of food and care for each other's offspring, so as to enable successful survival of each successive generation. Figure 17i shows a typical pathway up the ladder.

We've travelled through time from around 50 million to about 7 million years ago, observing the gradual climbing of the cooperative ladder by one squeaky little lone rodent to become a fully-fledged grunting primate functioning in self-replicating groups. Let's see where this goes next.

Figure 17g – Level 2 – Interaction Sequence

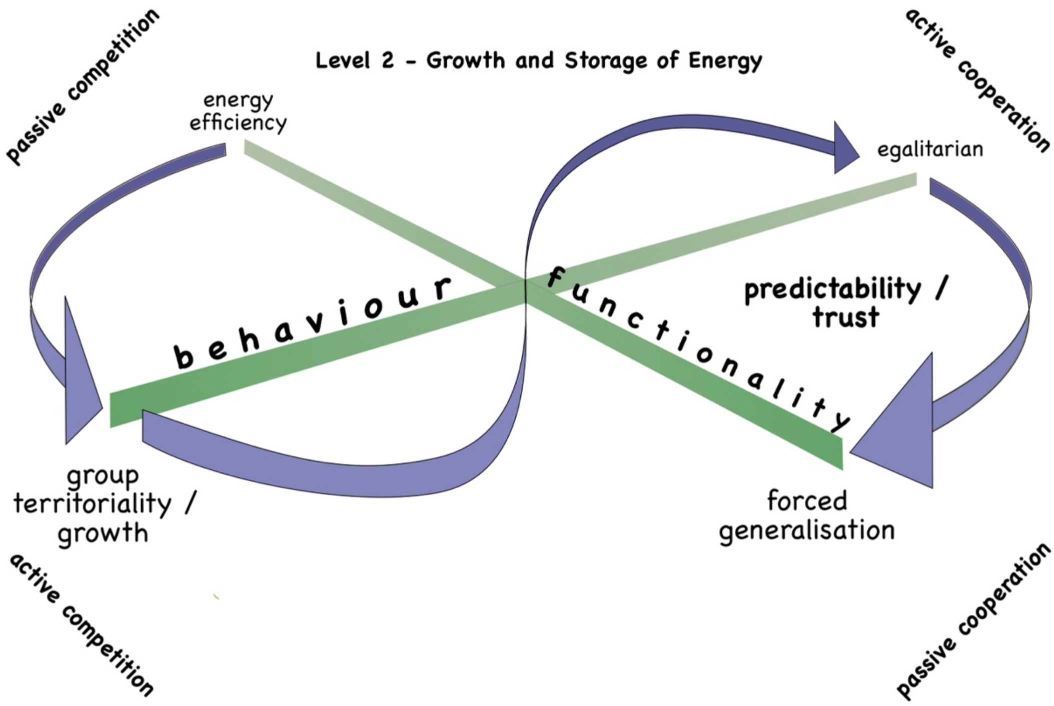


Figure 17h – Level 3 – Interaction Sequence

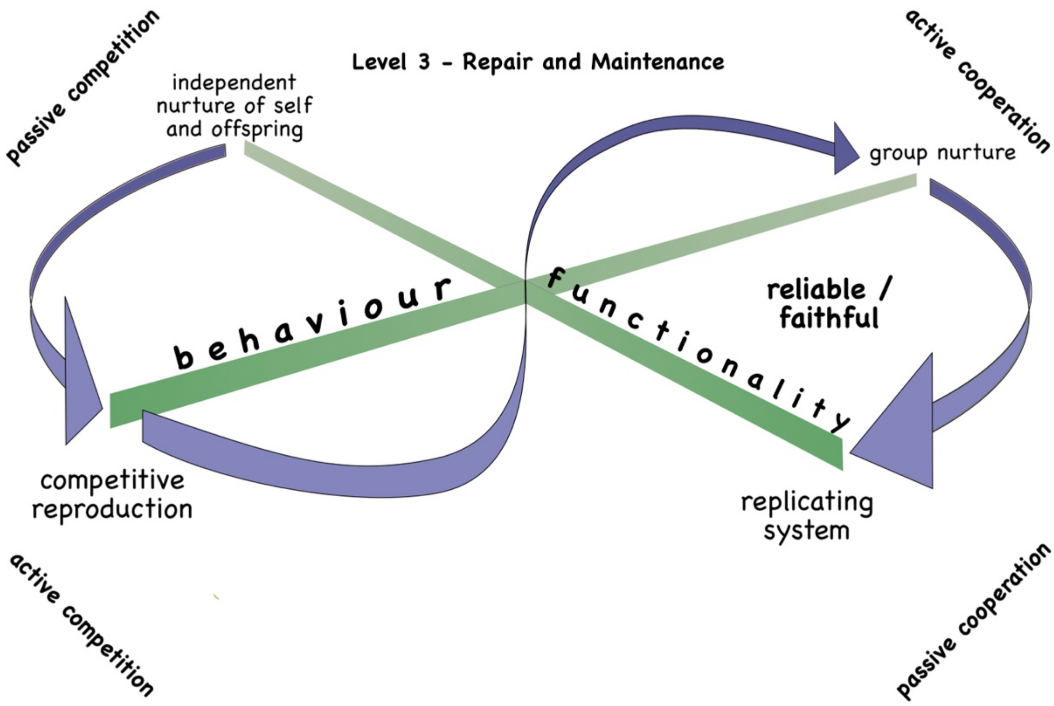
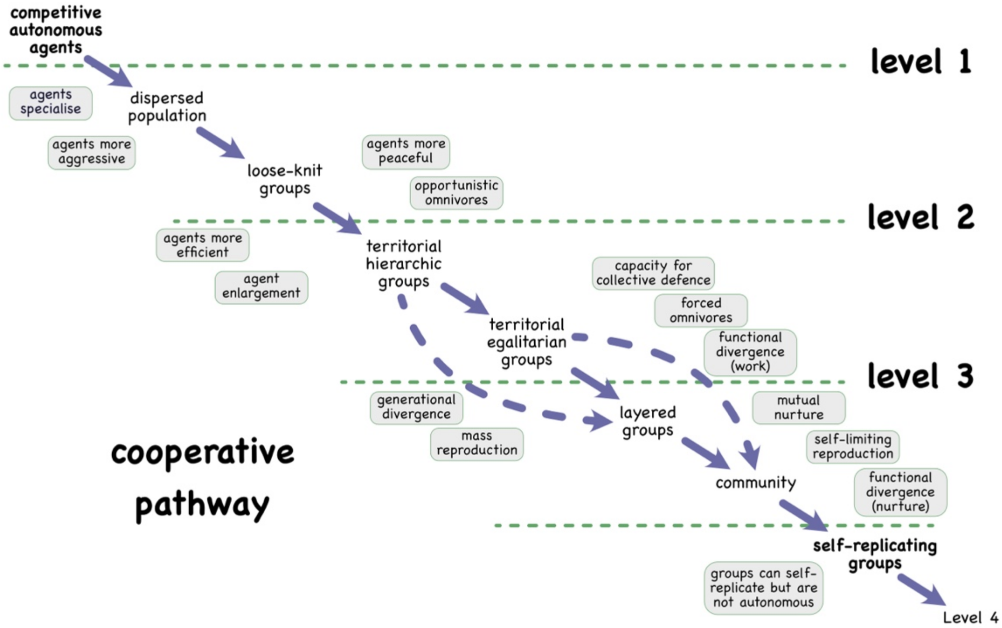


Figure 17i – Cooperative Pathway – Levels 1 to 3



Chapter 18 - The consequence of tribal living

"We made ourselves what we are."

After around 40 million years of genetic evolution from our original starting point, we find ourselves still in the African jungles. But the forest is now filled with clearly defined cooperating troops of primates. Each troop occupies its own area and survives off the steady supply of a range of foods within that locale. The troops are competing against each other for a combination of basic energy, security of energy supply and reproduction. This does not mean that there is no competition inside troops. Far from it. Each primate remains a coherent singular living system that has needs of its own and this will often pit them against each other, causing squabbles, the occasional baring of teeth and a bit of fisticuffs. But, by and large, they cooperate, being peaceful towards each other around food, being predictable to hold the line when threatened and being reliable, regularly reciprocating with nurturing related activity.

Being peaceful towards each other, they build a common tribal identity. Despite theoretically being direct competitors for energy, they accept each other as part of their existence. Sharing food day-by-day, they all become bound into a singular survival unit. Maintaining the peace within the troop is a critical part of their survival. Failure to do so may mean break-up of the troop and a poor outlook for any individual. To them, members of other troops are seen as competition for food and mentally conceived as being alien. This prejudice may be so strong that they might not even recognise those others as being of the same species, and therefore another potential source of food.

For them to survive as a troop, it is critical that they fully trust each other, so that when another troop encroaches their territory, they will stand together and aggressively defend it. Their held ground is their survival. Without it, they do not have an on-going supply of food. So, their lives depend on the coherence and integrity of the group. This gives rise to competitive selection for greater trust - the more intense the external competition, the more important internal Level 2 cooperation becomes. Those troops, who do not stand their ground as a unit, lose their territories and fall by the wayside.

Members of our early primate troops have also started to look after each other and collaborate as a group to rear off-spring. Those, where this behaviour is more pronounced, will be more successful in reproduction and their numbers will swell. This is going to cause these troops to need more forest area and they will unerringly push outwards their borders encroaching on neighbours. But there are going to be limitations to how big these reproductively successful groups can become.

Direct reciprocal nurture requires individuals to contribute time and energy to each other. Each primate is limited by how many others with whom they can maintain such close relationships. Consequently, at some point in size, there is a strong likelihood that factions will emerge - two or more communities within the same tribe. When young males are brought up in separate communities, even though within a singular territory, they have less direct connection to each other and will be less likely to develop as strong trust bonds with everyone else across the whole troop. The larger tribe may have more in number than their neighbours but may not be able to maintain the same structural integrity in the face of external intimidation. These factors work together to make the larger group less stable. Eventually, the troop breaks apart, forming two new smaller groups comprised from those erstwhile internally differentiated communities. And then the process starts again.

These reproductively successful tribes, through replicating, start to squeeze out all precursor groups until the forest is now occupied only by those who spend more time nurturing each other. As with predictability and trust at Level 2, at a group level we see competitive selection for greater mutual reliability and faith.

Now that we have a jungle landscape occupied by fully fledged Level 3 primate troops, capable of self-replication, what happens next?

Within the depths of the forest, where competition is most intense, this presumably leads to an evolutionary equilibrium. Population pressure will squeeze all troop areas down to a level, at which they bump up against the energetic envelope for their preferred food types. This may cause other types of competition to re-emerge, such as pushing them to generalise their energy preferences, becoming ever-more omnivorous. However, the more interesting changes now start to take place at the margins.

On the edge of the jungle as it merges into dispersed forest and savannah, our early primate troops continue this process of growing and splitting. When a division occurs, then one half of the original group may remain in situ, while the other newly formed tribe will be displaced. Further into the forest there are other groups occupying the space, so our new unit can't head into the familiar jungle. Rather they are pushed out of the forest and forced to start experimenting living in another landscape.

If you are an early primate born into a troop in the jungle, in your younger years you would have learnt from mentoring adults how to source food within your group’s territory. All members of the troop would have this common knowledge, know where to go and when to pick ripening fruit, what hazards to beware of and generally how to survive in your familiar environment. When it comes to defending the territory, the proof of trustworthiness is given through staying your ground, a fact that can be observed by your fellows. And proof of reliability is achieved through actions, where those who have done you favours will know, all too well, whether you are one who generally reciprocates. Telling the truth or lying is irrelevant when it comes to cooperation at Levels 1, 2 and 3, which are all very physical - the proof for all to see is in that primate’s observable daily behaviour and actions.

But when a troop as a whole group is pushed into unfamiliar territory, then things start getting complicated for them. As before, there are four ways in which individuals can respond.

Level 4 - Passive Competition. Whilst members of the troop may rely on each other for defence of territory and mutual nurture, when it comes to exploring an unfamiliar environment to find food, they seek to go-it-alone. On finding themselves in a new territory, they disperse as individuals or small family groups to search for food, perhaps reconvening each night-time for mutual protection in the dark. To be successful, they each need to become better at interpreting the environment around them, using all their senses to forage and hunt for food in strange places. They must also stretch their intellect to build a picture of the locality, so that they can learn to survive there. Those, who can do this, live and are more likely to pass on their genes.

This is competitive spatial intelligence, interpreted in its broadest sense including both the acquisition and interpretation of environmental information. It is a strategy, which is limited by the capacity of each individual to educate themselves about the whole of a new territory, to gain the skills and knowledge necessary to survive in that otherwise alien landscape without learning from other members of the tribe.

This group will share food when in each other's presence. But they won't bring food back to an encampment. They eat immediately whatever they can find. They do not communicate at all with each other about the whereabouts of food or dangers in this alien landscape. When there is either plenty of edibles or the geography is easy to interpret, then this troop may survive. But, when the rains fail, despite being members of an otherwise coherent tribe, this group of foraging loners won't survive long.

Level 4 - Active Competition. Everyone in the group is famished. Not knowing anything about the new territory, they split off in smaller sub-groups to look for food, just as have done those passive competitors. One of the families finds a bush full of berries. It's enough for them, but not much more. So, instead of shouting out their find, they gauge themselves. After all, none of the others will know that there's some ripe berries here and, once they're gone, the others definitely won't know. When they re-group, they lie and deny having found anything. This clearly benefits those few individuals today but leaves everyone else in the troop still very hungry.

As with the passively cooperating group, they only cooperate fully at Levels 1, 2 and 3 when they are together. When alone, they quickly revert to foraging for and eating their own food regardless of the implications on their brethren. But they take this further than the passive competitors. They learn to deceive and give false trails, sending other members of the tribe off on pointless journeys, while they gauge themselves on things they've found.

When food becomes scarce, they coalesce around leaders within the group, who have different ideas and strategies on how they might survive. Those leaders make promises to those following them, that if they honestly communicate where food has been found, then they will get some of that food or receive other benefits in-kind. Factions emerge and there is much argument about which direction the tribe should go to find food. The group ends up following an unpredictable course across the landscape, as the different factions vie for control.

Again, when the rains fail, this troop of liars won't survive long.

Level 4 - Active Cooperation. If that first family, who had found some berries, had instead called out their success to the others, then they would all have had a few berries today and all of them been more energised to seek food tomorrow. But, if everyone else is lying, what incentive is there to be truthful? There isn't much obvious benefit in the immediate present for any one individual to tell the truth over lying. But, looked at from a bigger picture, those tribes who do start being truthful to each other in unfamiliar territory out-survive those that don't.

Cooperation at Level 4 requires that individuals do not harbour information to themselves but instead communicate generally all that they know to everyone else in the group - honestly. This way the tribe can pool their knowledge. It also tends to lead to more egalitarian tribal structures. Members of the tribe are incentivised to be truthful to each other when they think that the information, which they share, will either benefit them or, at least, not be used against them. Strict hierarchic structures, as may have previously existed, are no longer so successful because juniors won't otherwise share their knowledge. Greater mutual respect is required and for everyone to become involved in decision-making. This may require the group to agree procedures for making decisions in cases where there remains disagreement on courses of action. This might include voting or something equivalent.

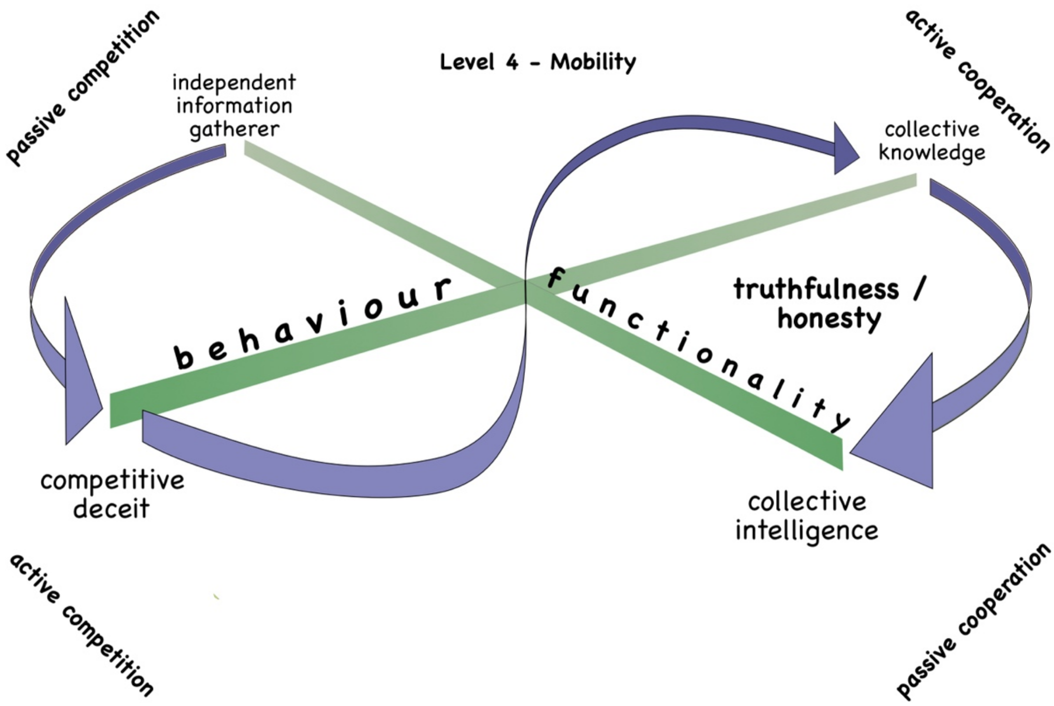
Being honest allows a troop to spread out across their territory to harvest foods and bring these back to an encampment. It allows the group to rapidly learn about new surroundings, using their collective senses. The ultimate outcome is that the group gains autonomy and the ability to inhabit new territories. But, as before, the heretofore innate competitiveness of lying to each other becomes internalised. At Level 4, this becomes expressed in terms of, to use modern parlance, influencers and critics. An equivalent in modern human society is the differential between politicians (thought leaders) and journalists (reporters and analysts).

Level 4 - Passive Cooperation. The cooperative opposite to competitive increases in spatial intelligence is for individuals to become skilled in different areas of knowledge. They can then exchange their expertise to mutual benefit. In the emerging primate tribe, this might include, for instance, one becoming an adept tracker and another an expert forager, knowing which plants to eat and which are poisonous. Together they are stronger as a team. But it requires appreciating that each is occupying a different knowledge area and will likely approach decisions from different perspectives or varying frames of reference.

Whereas Level 4 active cooperation requires sharing generalised knowledge, which can be verified: is there or isn't there a ripe fruit tree on the other side of the valley? - someone can check. When it comes to relying on different areas of expertise, it is no longer as easy to verify whether someone is telling the truth or not. Consequently, even further honesty and respect is required, for everyone to be confident that correct specialist advice is being given to the whole tribe. This goes beyond pooling of knowledge to full collective intelligence. The group is now capable of exploring and surviving in a wide variety, potentially even constantly changing, landscapes. The group might even get a thirst for continuous travelling.

These four alternative strategies are summarised in Figure 18a.

Figure 18a – Level 4 – Interaction Sequence



The Human Adventure

Once our early hominins had learnt to cooperate fully at Level 4, then the world became their oyster. They were now able to survive as a group in foreign lands, so long as they stayed together as a group, being peaceful, predictable, reliable and honest to each other. In fact, the challenges of navigating unfamiliar territory were now reduced to such a level that it would generally be preferable for a newly separated troop to go off and explore new places than to stay and compete with their erstwhile cousins. And so, the great human migration commenced.

Through their historic evolution the human tribes tended to survive best at around 150 heads. When they travelled and found verdant new places and thrived, they grew, divided, and frequently one subset would move on. Given the challenges associated with being such adventurers, there would have been further selection of the fittest, with those surviving improving their ability to function together cooperatively. But, as they spread out, away from erstwhile competitor troops, competition for food and meeting all their needs was much reduced. Further adaptations reverted to Level 1 passive competition, with tribes becoming specialists in the new locations in which they found themselves. Consequently, further interactional evolution between tribes was minimal compared to what had previously happened in the pressure-cooker of Africa.

This finally brings us to the start of chapter 10 and the first proto cities. If the above story has any validity, then the trigger for the emergence of cities must itself have been the consequence of intense competition - this time played out on the Anatolian highlands (modern-day Turkey) (or somewhere in the Middle East). A collection of Level 4 tribes, capable of autonomy across the landscape, clashed on those grassy plains. They likely fought for food and much blood was spilt (being Level 1 Active Competition between Level 4 Hominin Tribes). After a painful transition, they eventually merged into a super-tribe, giving rise to the first appearance of active cooperation at a tribal level (the tribes now acting as the initial agents). This provided the setting for the subsequent initiation of trade (Level 1 passive cooperation) and thereafter those first proto cities. And then the story repeats over with the same set of processes kicking into action to influence the progress of civilisation. In this regard, civilised human society is effectively a super-organism made from human tribes.

In the last chapter, we saw how Level 1 Passive Cooperation led to generalisation and our early rodent species becoming increasingly omnivorous. When Level 4 tribes of tool-making hominins started interacting cooperatively, then the same process took place at a larger scale. Where before individual rodents tried out different food stuffs, where their experimentation became assimilated into the group, now we see whole tribes beginning to specialise in different ways of sourcing materials, such as one tribe fishing and another hunting deer. Their different approaches then became assimilated into wider society through their interactions in marketplaces - those proto cities.

The formation of society was only possible because, through those 50 million years of prior evolution, humans had been crafted into creatures that are capable of being pleasantly peaceful, steadfastly predictable, religiously faithful and brutally honest to each other. Not that we are always all of these. It is simply that through our evolution we have developed these capacities, to apply when we see it is in our individual benefit to do so. That long time of slow genetic evolution provided a template organism, which needed little adjustment to a more social world. So, the subsequent formation of civilisation has undergone the same evolutionary process, albeit at a much larger population scale, in but an instant, because this time it pertained primarily to economic, social, and cultural evolution, rather than biological.

Evolutionary Psychology

Those identified social processes, discussed in part 2, are not a new phenomenon that came along with civilisation. They have existed throughout our evolution, operating at a smaller scale inside each tribe, as everyone interacted with fellow tribal members to meet their respective needs. That gave rise to us in our modern form, capable of cooperating from Levels 1 to 4. We have also learnt to be competitive towards people who we see as outsiders - prejudiced towards those outside our tribe (Level 1), distrusting of those in other bureaucracies (Level 2), unreliable with people from other communities (Level 3), and to lie to those supporting other movements (Level 4).

This evolutionary history has led to our current physical form, adaptable omnivorous creatures with bodies which are remarkably flexible, able to walk on land, swim, climb trees, manipulate the physical environment with our fingers and opposable thumbs and various other traits. But what of our psychological make-up? How have these competitive and cooperative strategies influenced the evolution of our minds?

Over the last thirty years a model has emerged within the psychological sciences, which has gradually gained increasing support and credibility. It is called the Five Factor Model (see Box 18a). It is an empirical theory derived from statistical analysis of vast numbers of psychometric tests. When you apply for a new job, they may ask you to complete a set of attitude and behavioural questions, which are designed to assess your mental aptitude. It is reported to be an assessment of your personality. You are presented with numerous different scenarios and asked how you might mentally and practically approach them. These questionnaires have become increasingly sophisticated, using clever approaches to prevent people from gaming the results. Huge numbers of these tests have now been run and then analysed. Using advanced statistical techniques, looking for correlations amongst answers, mathematicians have deduced that there exist five dimensions of human personality, on which every normal person sits. The best known of these is the spectrum from introvert to extrovert.

Box 18a - The Big Five Personality Types

Extraversion

The typical extravert is characterised as that person who flits around a party, having a quick chat to everyone. They thrive from being in social settings, whether amongst acquaintances or strangers, happy to make new friends and forever moving onto the next thing. They are likely to have a wide circle of friends but perhaps not have as deep relationships as their introverted counterparts.

Agreeableness

Someone scoring high on agreeableness is the perfect team worker, quick to fit in with their work colleagues and enjoys helping other people. Their opposite is someone who takes little interest in others and is much more focussed on what they need to get done themselves than being of assistance to those around them.

Emotional Stability

This is often referred to in its reverse as Neuroticism (probably just so the acronym of OCEAN works). However, the end of the spectrum that corresponds to Extraversion and Agreeableness is the opposite to being neurotic. Someone who is deemed emotionally stable can deal well with stress, rarely feels depressed and generally comes across as relaxed. The neurotic conversely tends to worry a lot, gets upset easily and is less able to bounce back from stressful events.

Conscientiousness

The conscientious person is typified by someone who expresses a high degree of thoughtfulness, has good impulse control (such as being better able to express delayed gratification) and tends to be goal-directed. Those who score low on conscientiousness may struggle with completing tasks and tend to be more disorganized.

Openness

Characteristics associated with this personality type include imagination and insight, open to trying out new things and tackling new challenges. They are happy to think about abstract concepts. The low scorer will typically resist new ideas and is less imaginative.

The Five Factor Model has a long gestational history going back to the work of Gordon Allport in the 1930s, one of the founders of personality psychology (as introduced in chapter 6). Its early origins arose from lexical analysis, looking for groupings of related words within our vocabulary on the premise that our language will have hard coded indicators of the way we think and behave. Breakthroughs came during the 1980s with the help of computers to analyse large datasets. Since then, this model has gained an ever-increasing level of consensus as a gold standard for assessing people's personality. But no-one really knows why there should be five aspects to personality, nor why these identified dimensions.

Here's a suggestion.

These five personality spectra relate directly to our needs and the Ideal Type interactions we have with others. The table below shows how they may relate. The spectra from, say, extraversion to introversion indicates a person's innate preference towards cooperating or competing at, in this case, Level 1 (Box 18b).

Box 18b - ideal types against Five Factors

1.	Level 1 - Energetic and Material Needs	Extraversion
2.	Level 2 - Security and Safety Needs	Agreeableness
3.	Level 3 - Health and Reproduction Needs	Emotional Stability (often labelled in the converse as Neuroticism)
4.	Level 4 - Information and Autonomy Needs	Conscientiousness
5.	Level 5 – Dexterity and Proficiency Needs	Openness / Intellect

The extravert is someone who readily cooperates at Level 1. They will happily share food and, equally, thoroughly enjoy flitting around a marketplace participating in numerous instantaneous interactions with others. The introvert, in contrast, will tend to keep things to themselves and is much less ready to share. Within civilisation, the extrovert is someone who readily explores new identities and fashions, where the introvert will stick to tried and tested foods and products.

Stepping up to Level 2, the agreeable person is ready to muck in and work closely with others to get things done, quickly adapting to new codes of conduct and other trust expectations. Counter to this, the less agreeable is inherently more territorial (both physically and virtually) in their behaviour and prefers to work alone. They will tend to diverge away to other work activities, promoting greater division of labour so that they can find their own niche.

The emotionally stable type is someone who will participate in the community, seemingly altruistically, but ultimately freely willing to believe in the humanity of others and that when they are in need others will step in to help. Conversely, the neurotic will seek to be much more independent in looking after their own health, and those of their immediate family, and not so amenable to rely on the support of relative strangers.

The conscientious person is far more likely to be respectful of others and value honesty, whereas less conscientious people tend to be far more liberal with the truth. The existence of the fifth personality type is suggestive that there are indeed five basic needs.

As an empirically derived model, there is no corresponding theory to explain why five and why these five. Researchers have been, quite understandably, grasping at straws to explain what these five factors truly represent. If what is suggested above is deemed to have merit, then this will help significantly to tease out our understanding of these personality types, what they really are and how to fully differentiate between them. By way of example, there remains much confusion over what Neuroticism really means and whether it should be deemed to be a bad thing to have a neurotic disposition or whether that's okay; we tend to look on neuroticism negatively, yet it must have had evolutionary benefits.

In addition to the spectra for each personality type, there is the question of relative strength of personality type. Someone may strongly prioritise Level 1 (introversion v extroversion) but pay much less heed to Level 2 (disagreeable and agreeable). To this end, we are each born with an innate disposition towards how we prioritise our personal needs. This helps to explain why some may end up as religious zealots, focussed on their future (perhaps afterlife) needs and willing to forego pleasures in the present, where others may work themselves to an early grave, seeking to amass a fortune. As explored in part 2, these behaviours are exaggerated through the interactions we experience as we grow up and grow old. But we each start with a natural tendency towards one socialising pathway or another.

We made ourselves

Our evolutionary line started some fifty million years ago with a lone protagonist organism. It was some sort of rodent-like creature that had gained the ability to climb to avoid predation. This species was a pure population - each individual competing against every other to survive another day, eating fruit when it could, surviving entirely on its own. Over the course of around 40 million years, this initial species split into a variety of branches, on each occasion giving rise to a sub-species, many of which have subsequently died out. Successful branches continued towards the present becoming gradually more differentiated until they could be deemed to be fully separate species, including the different types of primates that we have found lurking around the world's jungles.

The various sub-species would have each continued to evolve, becoming better at their selected specialisations - more adept at extracting certain food stuffs, more aggressive, growing bigger but otherwise not changing form, or changing their rate of reproduction. But across all the sub-species, one specific branch stood out. At each step members of this enduring species kept turning to cooperation to resolve intense competition. The path that this branch followed may have veered into some other alternatives along the way. Hence, for a while it may have become a little more specialised at some food, but then started diversifying. At another time it may have dabbled with competitive growth, enlarging from the original rodent size to full primate. It's rate of reproduction may have waxed and waned. But, when competition ramped up, each time the members of this species eventually turned to cooperation and progressed up the ladder, until eventually there existed a building block in the form of Homo Sapiens within Level 4 tribes, capable of beginning the adventure of civilisation.

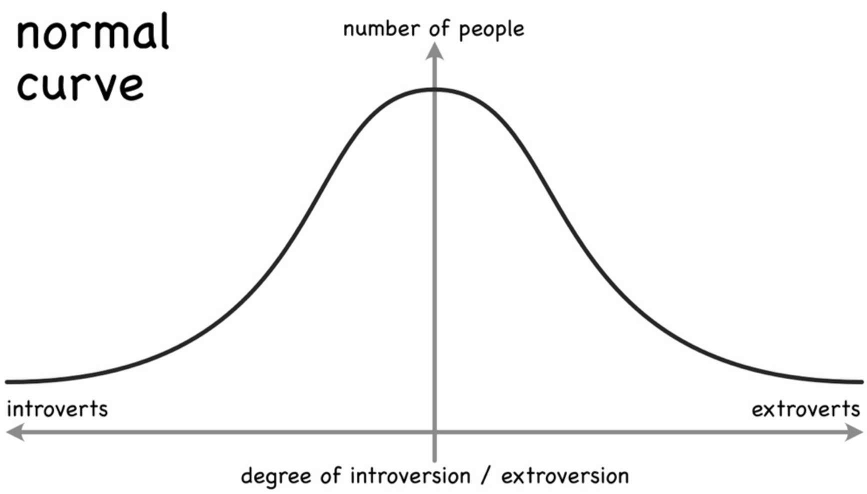
It's here that we then see the nesting of this approach to understanding competition and cooperation. After 50 million years our original cheeky rodent had progressed to hominins, which were able to form Level 4 tribes. These tribes are living entities, which have their own identity (Level 1), are structured and capable of self-defence (Level 2), self-replicating (Level 3) and autonomous (Level 4). These tribal systems now found themselves on the plains of Anatolia competing all over again at Level 1. The story of civilisation is how these tribes progressed up the same cooperative ladder, merging as they went to create larger social systems, eventually forming nation states and the whole of modern civilisation.

Competition within the populations of our ancestors was intense. In fact, the greater the competition, the faster we evolved, pushing us to form internally cooperative groups, which themselves competed fiercely against each other. To survive, members of these groups needed to learn to cooperate - sharing, trusting, being reliable and being honest. This shaped our ancestors' brains, selecting for those who could better express attitudes and behaviours corresponding to cooperation within their group and competition against others. The outcome is a normal curve (see Box 18c and Figure 18b) between introvert and extrovert, where most people can adapt to circumstances and be introvert when useful or extrovert where beneficial.

Box 18c - Normal Curve explained

Normal curves are also referred to as gaussian distributions or bell curves. They are symmetrical about the middle and represent a statistical distribution where most results lie in the middle of a range. Hence, for introversion and extroversion, a few people sit at either extreme, but most of the population fall in the middle of the spectrum, capable of being either introvert or extrovert depending on circumstances.

Figure 18b - Normal Curve



The real takeaway from this is to realise that we drove our own evolution. By the time we had reached early Level 4 tribes, exploring beyond the jungle, we were perfectly capable of defending ourselves from or eluding any other predators. The only real threat to our existence was other people and our own ability to survive in strange landscapes. And that's why, over the remarkably short period of 7 million years, and while giraffes slowly grew taller and elephants gained longer noses, we transformed from a grunting, chest thumping primate to a walking, talking, tool making human.

Now we might like to pat ourselves on the back for having made it all the way up the ladder to the point of starting again and thereby beginning the adventure of civilisation. But we have not been the first. For us to exist as multicellular organisms in the first place, it is the eukaryotic cells in our bodies, which preceded us on this journey by several billion years. Let's take a closer look at these small, very sophisticated living systems.

Chapter 19 - Organisms

"Multicellular organisms: the wonder of cooperation taken to its logical conclusion."

Cells are the building blocks of life as we know it. Everything, which we conventionally think of as living, of having some form of self-vitality, is made of cells. Organisms range from the smallest microbe, only observable with the strongest of microscopes, all the way up to soaring redwoods and ponderous blue whales. They constitute all those identifiable objects in our experience, which appear to have an ability to consume energy, grow and replicate themselves.

Cellular systems on Planet Earth are made up of two types of cells. All single celled systems, being the multitude of bacteria covering every surface in your home, represent prokaryotic cells. All multicellular systems - being, rather obviously, all those organisms constructed from more than one cell - are made using eukaryotic cells. The smallest true multicellular organisms have a few thousand cells. You have around 30 trillion.

There are a range of differences between prokaryotic and eukaryotic cells. However, the only pertinent ones to consider for this discussion are that eukaryotes are all much, much bigger (between 100 to 10,000 times larger) and hugely more complex than the prokaryotes. Both types can replicate, one dividing to create two. This replication process is what enables bacteria to multiply at an exponential rate and multicellular organisms to grow from seeds into soaring trees. Whilst scientists can describe in detail the replication process for different types of cells, they cannot explain why cells do what they do so well - dividing and multiplying. This universal characteristic of cells appears to defy our observations in the physical sciences, such as that drop of milk dispersing in your cup of black tea.

Geologists have surmised through analysis of rock strata that the first cellular life forms emerged around four billion years ago - being entirely small single celled systems, precursors to modern-day bacteria. It took some two billion years after that for the first fully functional multicellular systems to appear. It is a logical deduction that these multicellular organisms must have taken form somehow through interactions between the precursor single celled systems. Some hypotheses have been made, drawing on observations that certain earlier smaller cells appear to have been incorporated into modern eukaryotes. By way of example, every cell in your body contains mitochondria, which generate the energy to power the cell. These are thought to have originally been a separate type of bacteria, which somehow became enmeshed as a functional component in your eukaryote cells. The historic mechanisms that caused the formation of eukaryotes are unknown and nigh impossible to prove from studying ancient rock beds. It remains one of the big mysteries of the life sciences as to how cooperative eukaryotic cells eventually emerged from two billion years of primordial grey sludge.

Individual bacteria are manifestly competitive energetic entities. If you drop a few of them onto a sugary gel in a Petri dish in the laboratory, they will rapidly replicate, doubling in number every twenty minutes, until all the sugars (their source of energy) have been consumed. We all have experience of the competitive nature of bacteria from having eaten something ‘dodgy’, which contains some fast-breeding sugar-hungry bacteria in it, such as salmonella. The invading species quickly replicates and upsets our internal bacterial ecosystem - all those life-essential other bacteria living in our intestines, which make up our gut biome. Depending on how good your diet is, you have anywhere between 300 and 1,000 different species of bacteria within your gut. Amazingly, their combined populations exceed the number of your own cells.

Each cell in your body is itself a living entity. It may be much bigger and more complicated than those bacteria. It may normally behave in quite different ways, responding to triggers from the wider body of which it is apart in ways that are more cooperative and contributory to the successful functioning of the whole. But nevertheless, each cell is a competitive energetic system. If you doubt that, ask someone who has survived cancer - it only takes one cell to go rogue, stop abiding by your body's rules and evade your internal police system for you to be faced with a potential death sentence.

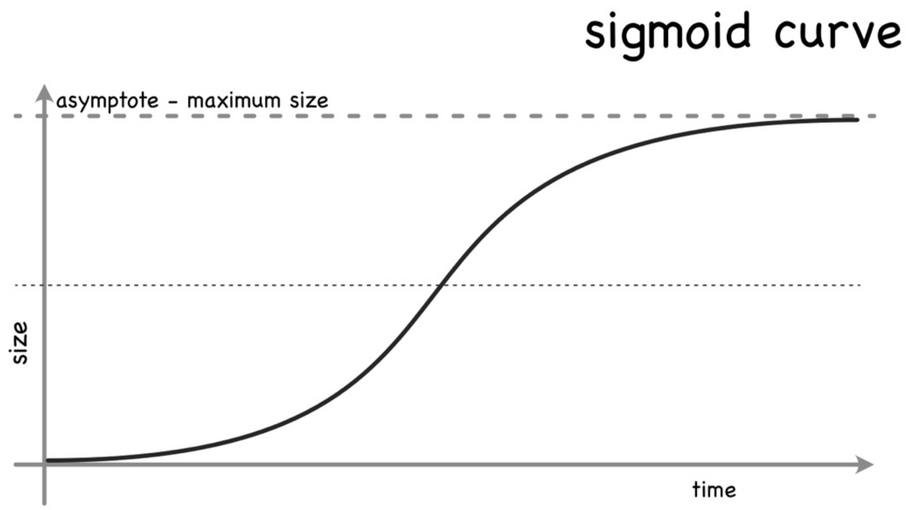
Prokaryotic cells can exist alone in the outside world. They may have preferred environmental contexts, such as inside your intestines. But it only takes one bacterium floating around in the air to land on something, such as a luscious strawberry, to replicate exponentially until the once tasty morsel has turned into a squidgy unappealing furry blob. Eukaryotic cells cannot survive alone. Like the lone human on the savannah, who has become lost from her tribe, sole eukaryotes quickly die when left out on their own and certainly don't replicate. They have evolved to be a cooperative part of something larger. Within multicellular organisms, this cooperative behaviour has been taken to its logical conclusion through mechanisms such as apoptosis - effectively cell suicide, otherwise known as programmed cell death - one of the attributes that gets turned off in cancer cells.

So, how did these eukaryotic cells come into being? Could it be that the evolutionary process, which ran its course over circa two billion years, was essentially the same as that already set out for the way a little furry animal transformed over fifty million years into grunting ape? It is impossible to deduce this through any historical record - all the evidence has been digested by intervening generations of microbes. Rather than looking back, we can examine current multicellular systems, to identify evidence for the competitive and cooperative layered processes already explored in relation to human society (tribal life and civilisation).

Multicellular Systems

Multicellular systems grow. They invariably start with a single cell, which replicates again and again to create a larger coherent entity, a unique system, which when it reaches an adult size for that species can produce new starting cells (seeds, eggs, sperm or equivalent). This applies whether the organism is too small to see with the naked eye or too big to be appreciated without taking a few steps back. Whilst growth of such systems may, after aeons of evolution, appear to be a tightly controlled process, it necessarily happens from the bottom up – each cell replicating to produce more cells. The overall process for all multicellular organisms follows a sigmoid curve (see Figure 19a).

Figure 19a - sigmoid growth curve



Sigmoid growth curves, also known as s-curves, can be found in many areas of our experience from growth of organisms to the construction of buildings. They apply to population growth, such as those bacteria multiplying in a Petri dish, replicating quickly until the sugar is all used up. If you introduce a new species to an ecosystem, its numbers will initially increase exponentially. But, as it approaches the limit of food availability (referred to previously as the energetic envelope, representing an asymptote, a maximum), the rate of growth rapidly decelerates – the top of the ‘s’.

A multicellular organism represents a population of cells, which follow the same growth path, rapidly increasing and then slowing down as they reach an asymptote. In an ecosystem, that limit is externally defined by dint of the food available to eat. For organisms, the maximum is internally set, the cells in your body abiding by some pre-defined limitation. If any of your cells stop cooperating, then they revert to their innate competitive nature. Cancer of one form or another ensues, for which there is very definitely no self-limit to growth.

In popular science magazine articles on the biosciences, there are frequent references to the controlling influence of the DNA. The DNA represents that long molecular code within each cell, which was earlier likened to a blockchain. It contains all the instructions required to control the formation, growth, and development of an organism. We rather loosely talk about the DNA ‘making this or that happen’. But the DNA within cells is itself an emergent phenomenon.

The modern synthesis construct for biology relies on the observation that cell replication is not perfect and when it happens the DNA code picks up errors, otherwise known as mutations. These can cause the next generation of a species - single or multi celled - to have a marginally different form or function, such as a slightly longer neck. These errors represent trial and error iterations tested out through the survival of real organisms living in the jungle, on the savannah or in the soil in your garden. Over countless generations, these mutations have eventually given rise to the current array of species on Planet Earth, including salmonella, redwoods, gazelle and us. Darwin's world of survival of the fittest is basically a filtering process, selecting for those fortuitous DNA mutations that have caused a new more successful organism, which can in some way outdo its peers within the competitive environment, the habitat, in which they exist. The DNA is then a record of such mutations, where each successful iteration is, by definition, a spontaneous improvement, recorded in the DNA of the next generation and all thereafter.

When an organism is born and grows, it effectively re-enacts all those evolutionary changes expressed by its generations of ancestors. If they had become more specialised, so does the modern organism express that as it grows. If they had experienced competitive growth for a while, then the new living system grows larger accordingly. If they had undergone competitive reproduction, so the new organism turns into a plant or animal which produces multitudes of new offspring. And so on. Each of these directions of progress took place uncompelled. For instance, wherever there are fractal structures, whether that be whole trees or the shape of your lungs, these have arisen through harnessing a natural growth phenomenon. And, in your body, you have 200 different types of cells. The mechanism of diversification, which led to this range, must be something which in the right circumstances happens naturally. So, everything encoded within the DNA and then re-enacted through an organism's growth and development must be the result of a spontaneous process - as freely as the milk dispersing in your cup of tea.

Despite observing non-vital systems growing, such as snowflakes, there is no part of our physical sciences that can readily explain how growth happens. And there is certainly no way to explain how a population of cells might spontaneously self-limit. Given more sugar, the bacteria in a Petri dish would just keep on replicating. Yet, somehow, the cells of your body have evolved not to, even though they are supplied with a continuous flow of energy.

The Processes of Life

Can a process-driven explanation help?

This sigmoid growth pattern is what would be expected through the influence of the identified priority processes - Levels 1, 2 and 3. Level 1 is the initiating process, instigating a new unique life form. Thereafter, it acts to power an organism, ensuring a continuous flow of energy to drive internal processes within, including growth, repair, and movement. The Level 2 process uses the energy supplied through the Level 1 process and gives rise to exponential replication of the unit parts, the cells. It is driven by the system spontaneously seeking to increase its access to energy sources and to store energy. As the system grows, the Level 3 process takes on an increasingly important role, managing, maintaining, and repairing the structures created through the Level 2 process. As an organism matures, energy is increasingly diverted away from the Level 2 process towards the Level 3 activities, maintaining and repairing the so-formed structure.

In the natural world, we can observe that there are two major categories of multicellular systems. One of them, plants (including fungi), represent those systems which have reached Level 3 levels of cooperation. They are inherently static. Within plant systems, the tension between the Level 2 and Level 3 processes is not fully balanced. It means that growth slows down to a crawl but never quite stops. These systems are perpetually enlarging, albeit the rate of growth relative to the size of organism diminishes until full grown oak trees do not appear to increase in size at all. But they do keep growing.

The other category is the animal kingdom, being everything that can move from the smallest worms and fleas to the largest elephants. These are all Level 4 systems, which have gained autonomy. Level 4 systems do formally limit their own growth.

Now, the Level 4 process in the domain of human society enables us to manage our lifestyles to achieve a work-life-balance. Through processing information, it proffers the ability to see things in perspective, to expend energy in a way which properly balances food consumption with work, regenerative rest and sport. In the biological context, the same natural mechanism has allowed mobile systems to self-manage, to formally limit the growth process so that once full-grown an organism's body only replaces what is lost. Your skeleton reaches a certain size and stops. Clearly though, if calorific intake exceeds expenditure, then the Level 2 process will naturally put aside and store the spare energy as fat.

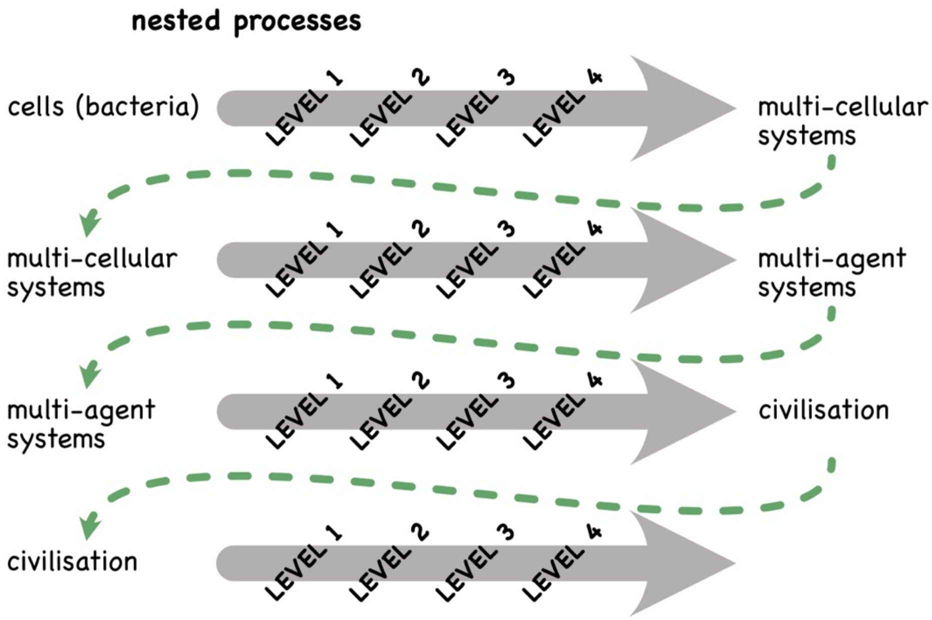
It is this remarkable balancing of processes which allows you to have a new pair of hands, maintaining a consistent size and form, every few years, as new cells are incrementally formed to compensate only for those that die. Not only do we achieve and remain at a fixed size once adult, but our growth through childhood is also extremely well controlled. Because of the inherent exponential nature of growth, it only takes very small discrepancies in rates at the outset (say, 10%) to produce large differences in final size (say, more than 100%). But the regulation is so good that your hands are observably the same size. And, across our species, most people fall within a relatively small range of sizes (notably distributed as a normal curve). The precise balance between metabolic rate, growth, and maintenance, which has been achieved through evolutionary iteration, is quite awe-inspiring.

When combined with the observed sigmoid growth curve, these observations suggest that there must indeed exist a natural tension between a set of competing processes, causing different stages of growth, which in the case of animals ends up fully balanced to achieve and maintain a fixed adult size.

Cells as Agents

The evolutionary process, outlined for that squeaky little rodent climbing the cooperative ladder to tool-bearing hominin, can be generalised. That starting organism can simply be referred to as an agent. This agent can be any identifiable energy consuming system, no matter what size or shape. At the outset, as per the beginning of chapter 17, there is a population of self-same competing systems, expressing no cooperation between them. Following through the whole process with bacteria as the agents, one starts with a population of competing single celled bacterium and finishes with an autonomous (Level 4) multicellular organism (see Figure 19b). If starting with a multicellular system, then the end point is an autonomous group, such as a Homo Sapiens tribe. And commencing with tribes, the end point is a human civilisation - the fruition of which we have yet to see. The implication is that a fully Level 4 society would be autonomous, whatever that means – leaving Planet Earth?

Figure 19b – Agents to Systems, and again



Returning to Level 1, there is a fundamental split: does a population of competing self-same agents rise to the challenge of sharing quanta of food and flip over to Level 1 cooperation? If our originating species remains competitive at Level 1, then over the course of time we may see emerge a variety of similar other species, diverging apart, each specialising in a type of energy and niche within its ecosystem. They may diversify into a whole range of different forms. But one thing will remain certain. If those agents are cells, then, without Level 1 cooperation, all these subspecies will remain single-celled systems.

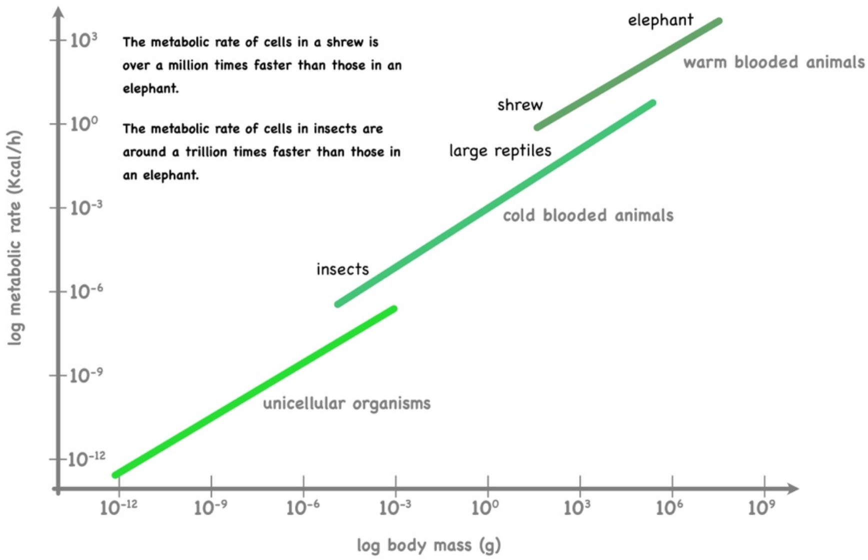
The degree, to which each new identifiable subspecies will be aggressive, will depend on how intensively they compete for their preferred source(s) of energy. If there is heavy predation or other mechanisms, which keep population levels well within their energy envelope, then such off-shoot species may never need to progress to become aggressive, nor cooperative. These specialists emerging through Level 1 competition will also compete at Levels 2, 3 and 4. But the intensity of competition between them at these higher levels will always be less fierce than that experienced at Level 1 and will be expressed to reducing degrees for higher levels (as discussed in chapter 16). Consequently, each subspecies will be driven to evolve down narrower and narrower ecological niches, becoming highly specialist at accessing and digesting certain food stuffs. But the degree to which any new species may become, say leaner or larger, will be relatively limited. Over eons of time there will, consequently, be relatively little change in the species' sizes and reproductive strategies.

The bacterial world is clear evidence of agents at the cellular level, which remained competitive at Level 1. Around the globe, there is a vast number of different species of bacteria, measured in billions, if not trillions, which have been given form through four billion years of evolutionary trial, error and diversification. All these different species have diverged over time to have very different shapes and varying metabolic functions, helping them each to dedicate their existence to a particular ecological (or energetic) niche. But, relative to the level of transformation experienced by eukaryotic cells, they have not fundamentally changed either in size or much of their functionality (such as how they replicate), despite the passage of billions of years.

If a population of self-same agents switch to cooperation at Level 1, then they are taking the first step in a long journey towards creation of a new multi-agent system – in the case of bacteria, to create a multi-cellular organism. Once a population of self-same agents have taken this initial step, then there is a huge variety of different pathways which they can follow, progressing up the cooperative ladder. These pathways affect both how these agents compete or cooperate between themselves and consequently the size, shape and functionality which they themselves come to express. And the whole systems, which they form, all those multi-cellular organisms, can manifest in a huge variety of ways, demonstrated by the full variety of multi-celled systems which have existed over time – noting that the variety of species alive now is a very small fraction of all the species that have ever existed.

As the agents, being the cells, explore these different pathways of cooperation, the influences on their form and functionality can cause significant differentiation from the originating prokaryotic agent, as evidenced by both the difference in size between prokaryotic and eukaryotic cells and the huge variety of sizes amongst eukaryotic cells. And then their functionality can be driven to change too, leading for instance to the difference in the cellular-level metabolic rates across the animal kingdom from insects to elephants (see Figure 19c).

Figure 19c - metabolic rate graph



As cells have progressed up the cooperative ladder, they have learnt to cooperate in more and more sophisticated ways, requiring the emergence by mutual agreement of controls on behaviour to preclude free riders. Just as we have explored in the human domain, where we see the appearance of money (to track transactions), the rule of law (to maintain trust) and religion (to promote mutuality), emergent eukaryotic cells went through the same process of forming mechanisms to ensure each agent contributes to the success of the whole. At the cellular level this is done through chemical and electrical signalling. Eventually the level of cooperation between cells has progressed to the point of creating an internally regulating system, which, in the case of mammals, maintains an amazingly precise temperature regardless of how hospitable is the outside world. And the cells themselves have become such cooperative entities that, if need be, they will undergo procedures such as apoptosis for the benefit of the whole.

If this process-driven approach has validity and does indeed apply across a range of scales, cells to humans, then the process of cellular replication can be better appreciated. Looking to the human domain and the replication of tribes, we can see reproduction of component agents, the hominins, led tribes to grow. When those hominins had learnt to look after each other (Level 3 cooperation), then this progressed faster and more effectively. But the agents (say, humans in tribe) had evolved to a certain normality in terms of how strong they could bind together to create a spatially structured system - such as the level of trust enabling a tribe to defend its territory. If a tribe's population grew beyond an evolutionarily defined normal size (thought to have been about 150 heads), then the level of trust was insufficient to maintain the tribe's structural integrity and it would split. Its internal communities would then create two new entities.

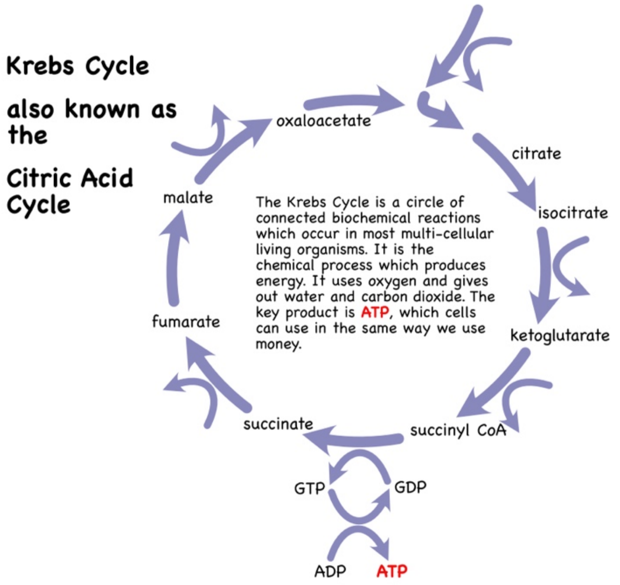
Conceptually the same mechanism takes place at the cellular level, albeit, after billions of years of evolution and an infinite number of iterations, this follows a very tightly controlled procedure to ensure that the two new wholes are each functionally capable of repeating the process, again and again and again.

Communities arise from reciprocal actions between component agents, contributing to each others' health. Without these interactions, such as a monkeys removing tics from others' backs, girls taking turns cutting their hair or a couple going out for a date, communities cannot exist. But without internal communities, systems cannot successfully undergo replication and/or reproduction. So, where actions at Level 2 allow a group of agents to occupy and defend space, when a group fully embraces reciprocal healthcare actions at Level 3 it allows for the whole system to undergo replication.

This analysis can be generalised to appreciate that the Level 2 process is inherently a linear mechanism. It involves directional flows of materials and energy, as explored previously in relation to bureaucratic systems. It is this that allows systems to grow, whether we are looking at trees or civil services. Energy generated in the leaves of plants flows back into the structure, enabling materials to flow in the other direction - just as with human bureaucracies. Innate competition between cells leads to the branching of these systems, facilitating more growth which generates yet more energy. It is a positive feedback process. This is why such systems express fractal structures, where each green tendril can grow and divide, repeating identical form, spreading outwards to catch evermore sunlight.

In contrast, Level 3 processes are inherently cyclic - ‘you scratch my back and I’ll scratch yours’. Biologists and biochemists have come to realise that cyclic chemical processes are ubiquitous in nature. They are essential mechanisms to enable living systems to maintain themselves. Furthermore, cyclic systems lead to oscillatory behaviour, such as heart beats, circadian rhythms, and menstrual cycles. These cyclic processes operate at all scales, from within the functional elements of cells all the way up to the whole of your multicellular body. Your immune system is especially cyclic. Such processes are frequently nested (see Figure 19d), with cycles inside cycles. Whereas the Level 2 growth process can rapidly enlarge systems through repetitive structures, such as fractals, it is the Level 3 process which enables replication of functional components and ultimately of wholes.

Figure 19d – Full Krebs Cycle



The construct presented here is by no means perfected. There are still various glitches to iron out. But it is hopefully the start of a conversation about a more advanced way of understanding evolution of life on Planet Earth. Did the cells, of which we are made, go through the same stages of evolutionary progression as we seem to have done at an animal level and are now doing for whole societies? It's quite a sobering thought to realise that we are by no means unique in that respect. It takes us another step along that path of realising that we are nothing special, just a natural consequence of the universe we inhabit. But, if this approach does indeed apply at a range of scales, from cells to societies, we are forced to face the question of whether the same set of layered processes apply to systems below that which we conventionally think of as living - to the atomic world. We'll return to this puzzle in part 4.

Chapter 20 - Ecosystems

“The arena for life and death.”

When self-same agents learn to cooperate, they set out on an evolutionary path, which can eventually lead to the emergence of a newly evolved larger entity. They first come together through the sharing of quanta of food. Thereafter, this group is competing as a unit with an outside world, including other groups of such self-same agents (say, competing troops of monkeys). To succeed against the external competition, the group must become increasingly internally cooperative.

As agents have defined lifespans, the original set become replaced by generation after generation (the monkeys growing, reproducing and dying, cycling over and over). This provides scope for the constituent agents to change both behaviourally and functionally through genetic mutation. Survival of the fittest is now selecting for those agents which can better share, are more predictable, are more reliable and communicate honestly. This allows the larger whole to gain an identity, hold onto its structural integrity, maintain itself and, ultimately, move with purpose. Evolutionary pressure eventually gives rise to a larger entity, which has a high level of internal regulation, is stable in the context of an outside hostile and fluctuating environment and is capable of coherent movement.

The progress towards achieving stability within a cooperative entity is thereby quite understandable. Ecologists and geologists have, however, discovered that ecosystems also express a remarkable degree of constancy. Yet ecosystems are competitive environments, are they not? They are the context in which survival of the fittest plays out within species, with all those self-same agents, or groups thereof, competing to survive. Ecosystem habitats are also the arena in which different species appear to battle it out, whether that be grey and red squirrels being first to the acorns or predation, where you can watch on your TV screen a sleek leopard chasing a daintily prancing gazelle and closing in for the kill.

Analysis of fossil records has given rise to the notion of punctuated equilibrium. Ecosystems can seemingly remain very constant for eons of time, measured in hundreds of millions of years. Then, suddenly, in the space of, say, ten million years, they will undergo radical change. Those long periods of minimal change appear to be the norm. The intervals of transformation are presumed to arise from external factors such as major volcanic episodes or catastrophic asteroid strikes. These episodes cause large scale transitions in the planet's climate over a significant number of years, allowing, by way of example, mammals to displace the long-established land-roving dinosaurs.

If they are competitive environments, then why do whole ecosystems and the species within them exhibit such constancy for so long? And, are changes, when they do happen, always triggered from the outside? Using the model of a layered framework of competition and cooperation, let's try and answer these questions.

Energy Landscape and Biodiversity

The emergence of cooperation can be explained through recognition that energy comes in quanta - discrete lumps of food. When looking at competition across the ecosystem, it is also necessary to appreciate that there is not a continuous spectrum of energy. Food comes in distinct types. The range of foods within an ecosystem can be construed to be the energy landscape. As most food in any ecosystem, if not all, comprises the organisms within, whether alive or dead, then in effect that energy landscape comprises the full mix of organisms within an area.

The common way to refer to this energy landscape is the term ‘biodiversity’. This is generally understood to equate to the number of different species in an ecosystem, perhaps simplified down to the quantity found within a defined area of ground - say a square metre or square kilometre.

Ecologists have come to appreciate that greater biodiversity gives rise to greater stability in an ecosystem. By way of example, compare the daily temperature profile in a jungle, such as the Amazon, to that experienced in any desert. In richly diverse rainforests, there is relatively little variation in day-night temperatures. In contrast, deserts heat up to baking hot levels in the sun and cool off to freezing temperatures at night. Jungles also capture water vapour and maintain a humid environment, which is conducive to a greater number of species. There appears to be a feedback loop, such that the more species living in a habitat, the more stable they can make the environment, which allows for yet more species. This diversity is generally thought to make ecosystems more robust and better able to recover after natural catastrophes, such as rebounding from a forest fire, bad storm, or a nearby volcanic eruption.

Biodiverse systems comprise complex food webs. These are made up of large numbers of simple food chains - a familiar concept since it is part of early years core biology curriculum. The leopard chasing after, killing, and then eating a gazelle is a single link in a food chain. Food chains tend to be cyclic. Very simplistically, grass grows, the gazelle eats the grass, the leopard eats the gazelle and later the leopard defecates, which provides fertiliser for more grass to grow. In any mature ecosystem, there are countless food chains, all interlinking and crossing over each other, all being parts of larger cycles, contributing to that complete food web.

In organisms, stability and self-regulation is facilitated by cycling of energy and materials between agents in the system, facilitated by Level 3 interactions. Through these mechanisms, the individual agents, such as the cells in your body, are kept alive and allowed to thrive, so long as there is a baseline flow of energy to allow them to participate in such reciprocal interactions. In ecosystems, it is the complete opposite. It is food webs, relying predation and on organisms having limited lifespans, which facilitate the cycling of energy and materials through the system, thereby enabling a habitat to retain such energy and materials within itself, contributing to its on-going stability.

The rational deduction from this is that all those links in the food chains should rather be thought of as cooperative encounters, not competitive. Whilst the leopard chasing a gazelle is a competitive moment from each organism's perspective, at a systemic level these two species are really cooperating to help maintain the constancy of the whole system.

Energy Channels

The normal way to describe food chains and thence webs is that, through predation, energy and nutrients flow from one species to the next (see Figure 20a). This is technically correct. But it would perhaps be better to think that it is the organisms themselves, which operate as channels and stores of energy and nutrients (see Figure 20b). The actions of predation or carrion, when one thing eats another, represent junction points between these flows. Hence a growing redwood, as it rises up through the canopy, is itself a flow and store of energy and nutrients (a channel). When it ultimately falls over after 4,000 years, it relatively quickly decays, its accumulation of energy and nutrients passed onto a variety of other species (a junction). This way of viewing an ecosystem is a subtle, but important, alternative perspective.

Figure 20a – Conventional Food Web Depiction

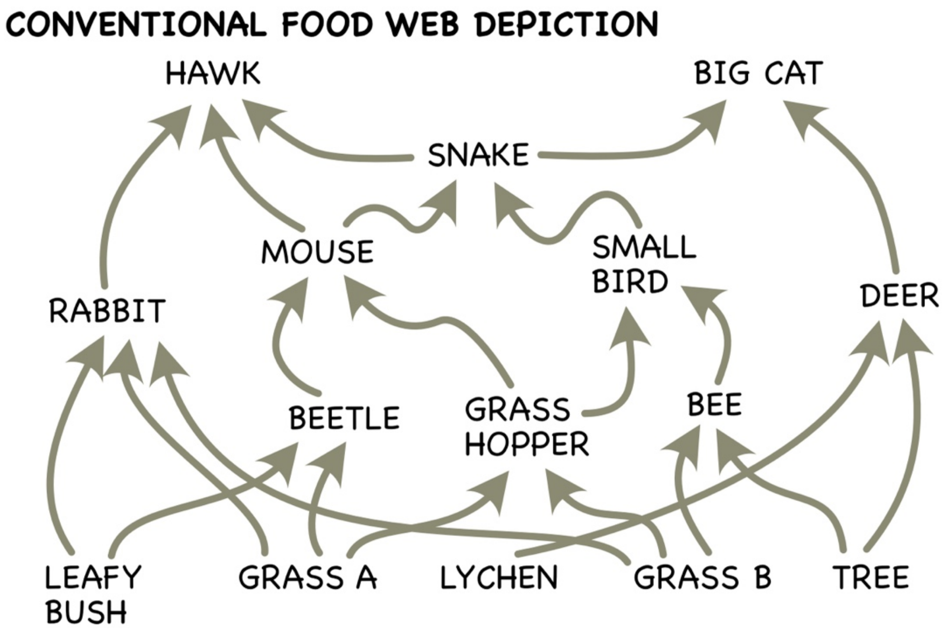
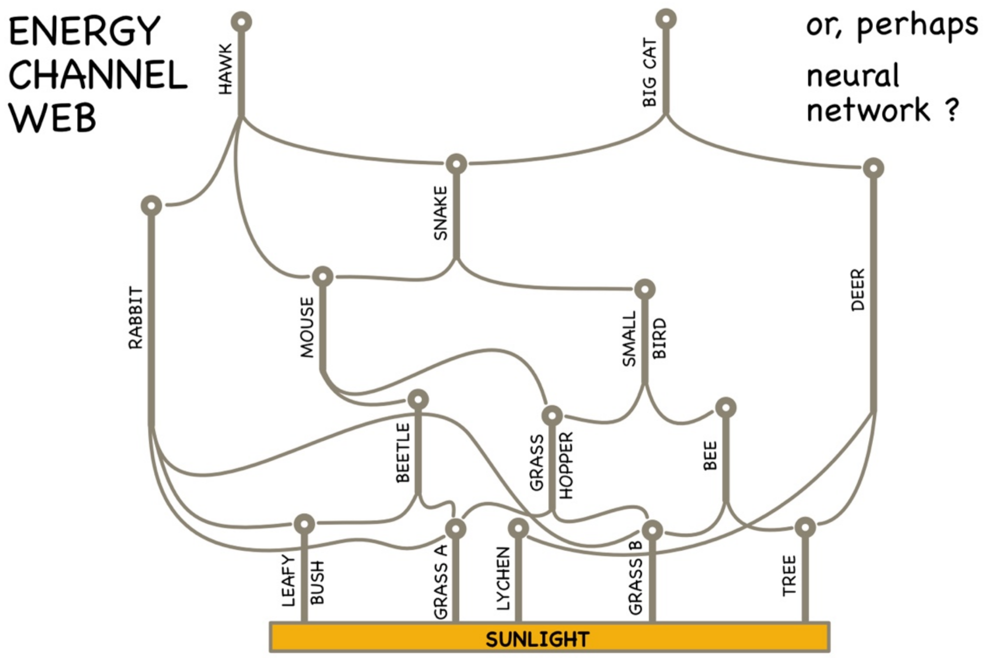


Figure 20b – Energy Channel Web



Thinking of the organisms as channels, then the more organisms there are in any area of the jungle, the more energy and nutrients are contained therein, cycling over and over - sometimes in months and years (grass to gazelle to leopard, back to grass), other instances over millennia (growing trees). This total quantity of energy and nutrients contained within living things makes up the total biomass of a system. The full spectrum of energy channels, creating junctions, forms the whole energy landscape.

As with biodiversity, biomass can be measured by 'per square metre' and is obviously greater in the jungle relative to the desert. The rainforest captures in-coming sunlight and converts this into new plant growth, producing food for other species, starting a cycle which ends up with more nutrients in the soil for new plants. The energy is absorbed and held within the entire system, having the overall effect that the forest maintains a humid environment and a relatively stable temperature through the night. In contrast, the relatively lifeless desert sands warm up during the day and then emit all that temperature back out to space when darkness descends.

Now, if you consider that the most intense competition is between self-same agents, then the realisation that highly differentiated species are effectively cooperating should not be a surprise. The leopard and gazelle are, after all, not competing for the same food stuffs. So, looking at the wider energy landscape, the further apart two species are as channels of food on the overall spectrum, then the more opportunity there arises for the emergence of cooperation, for one channel to connect at a junction to another. There is, however, more to this than just one creature eating another.

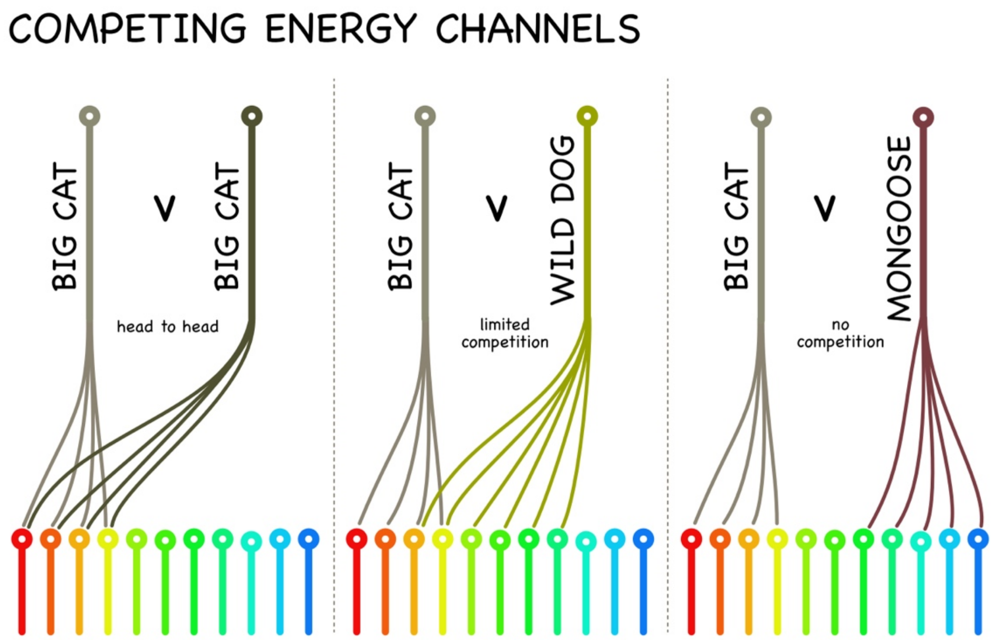
Specialisation on the Energy Landscape

If you were to introduce a new species into an established ecosystem, then it will need to fit into this web of channels and junctions. Let's say you added big cats into an environment, in which there was an incumbent species of wild dogs.

The felines will be driven by hunger to find sources of food, being suitable junctions in the existing network. They will form a new flow of energy and nutrients. If there is already an equivalent channel of energy in the form of another species reliant on the same set of junctions, in this case the canines, then this will pit the two species against each other. Competing head-to-head, then chances are there would be a winner and a loser species - in this case, say, the dogs become displaced from this region.

The newly introduced cats may be competing against other existing species. But, the more different their diet is to those other species, the less would be the level of experienced competition. By way of example, perhaps the cat is a leopard and, on occasion, it eats something which is normal food for local mongooses. These look a little like land-based otters, a little larger than meerkats. They are also carnivores and eat small mammals and insects. The leopards prefer larger game and will rarely come to directly compete against the mongooses, which form a channel mainly reliant on a different set of junctions (see Figure 20c).

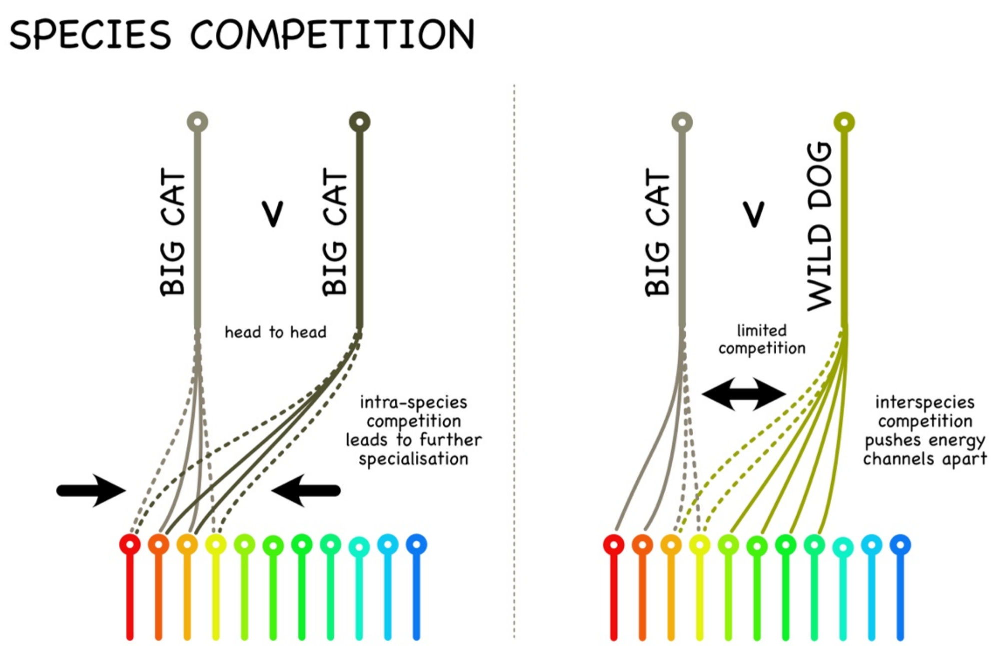
Figure 20c – Competing Energy Channels



If our introduced species of cats were successful, then they will compete against each other. With the availability of energy limited (say, only so many kilograms of their preferred prey to hunt in each square kilometre), then this will force expansion of the population outwards, pushing individual organisms into new ecosystems in neighbouring territories. These other environments may require adaptation of our cat species. Genetic drift mutations will be selected for, gradually leading to the cats in the surrounding areas specialising in their own unique ways. Eventually, there will be a range of different species of cat - a patchwork quilt of different cat types spread across the wider landscape. This gives rise to the well-known and well-catalogued spatial diversity of species and arises from Level 1 passive competition.

Within each ecosystem, the leopard descendants will need to remain the most competitive organisms for the energy available from their chosen junctions in that area. Over time, competition between the cats (intra-species competition) will drive them to become ever more expert at sourcing those types of food stuffs. Random genetic errors will only ever propagate through generations if those mutations are either beneficial for the leopard's selected energy channels (say, chasing gazelle) or are neutral. The intra-species competition hones the organisms to become better and better at what they do best - ever-increasing specialisation, providing a specific dedicated energy channel within the ecosystem, connected to a discrete set of junctions. In practice, this means that the leopards become faster and faster runners, more and more effective at catching gazelles. Meanwhile, interspecies competition drives variant species to minimise overlap, such that the leopards and mongooses focus separately on what they each do best. This pushes identifiably different energy channels apart (see Figure 20d).

Figure 20d – Species Competition



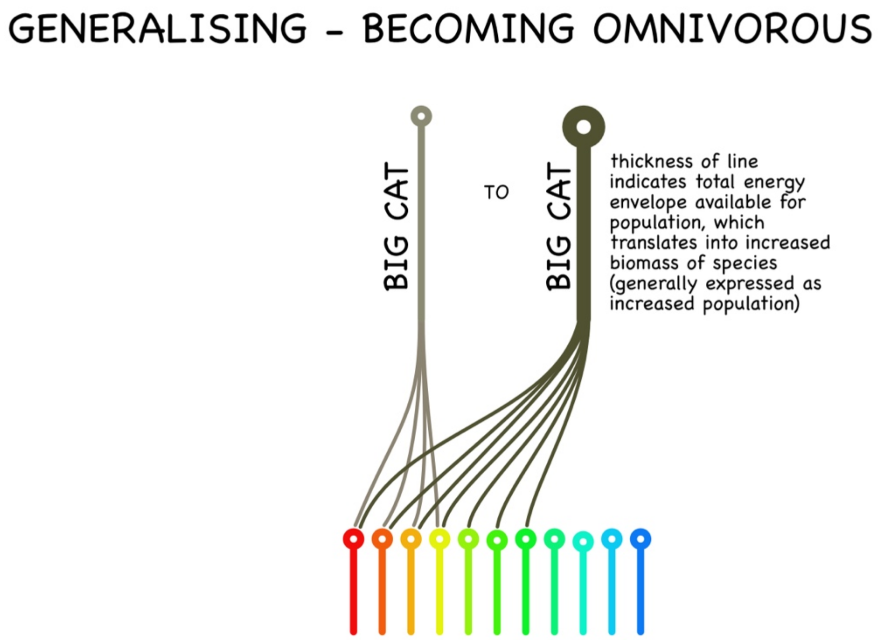
Through effective predation by the leopards, the gazelle numbers are kept below the level at which they might otherwise keep bumping into the energy envelope in the locality. This reduces the intensity of competition experienced between the gazelle, thereby preventing them from evolving to gain further levels of cooperation. And so, the gazelle remain in perpetuity prey for the leopards, unable to progress up the cooperative ladder. Competition at an organism level, representing systemic cooperation at a species level, effectively keeps the two species in an equilibrium state, preventing either from evolving substantially away from their current forms. Counter-intuitively, they are dependent on each other.

So, the food chains enable the cycling of materials within an ecosystem. But the competitive dynamic relationships between organisms, which equate to systemic cooperation, keep the network of energy channels static, maintaining constancy across the whole system. Hence, and so long as the global climate does not change, ecosystems can remain stable for long epochs. Until, that is, a species upsets the balance from the inside.

Generalisation on the Energy Landscape

When intra-species competition changes to Level 1 cooperation, then individual organisms become both able to try out other food types and then pass on such dietary exploration to their peers and to the next generation. Level 1 passive cooperation can allow organisms within a species to begin tentatively to put toe holds onto other junctions in the network without becoming, at least initially, dependent on those other energy channels (see Figure 20e). If that cooperating species is successful, then, as it probes becoming increasingly omnivorous, it can increase the flow of energy through its own channel and begin to compete with a wider range of other incumbent species. Its success increasingly lies in its diversification of energy sources. As the species now functions in groups, this exploratory behaviour becomes culturally embedded and any offspring with a mutation, which facilitates this widening range of food intake, will be more successful than their group peers.

Figure 20e – Big cat expanding food options



Cooperation can give a species a competitive advantage that allows it to progress ahead of all the other species and begin to impact the network from the inside. If a species becomes sufficiently successful and fully omnivorous, then it can begin to dominate more and more junctions in the network, causing an ever-increasing flow of energy through its own channel. This manifests in terms of population increase. This is a critical contributor to its ability to rise up the cooperative ladder - population success drives more intense competition at higher levels, forcing the agents to explore increasing degrees of cooperation within their now competitive groups.

Taking this to its logical conclusion, we now see us, the very omnivorous humans, who have dispersed around the world to eat all sorts of different food stuffs. Through our historic success, we gained the ability to displace countless species from their existing channels, hunting many close to extinction even in our tribal days. But also exploring lots of new plant-based food stuffs. The result has been an explosion in our population growth, as we divert more and more energy channels to our own needs. Nowadays we have gained the ability to re-arrange the whole food web as we see fit, discarding all those energy channels which we don't see as essential. It is for this reason that people are now quite rightly suggesting that we are entering a new era of Earth - the Anthropocene - which will be seen in the geological strata as a major transition point in the Earth's biosphere.

We humans have very definitely left the garden of Eden. Where our long-distant tribal ancestors existed as an integral part of natural ecosystems, over the course of the last 10,000 years, and especially during the last 1,000, we have progressed to such a point that we are now capable of converting or destroying whole landscapes to the point that, regardless of their previous levels of diversity, they are unable to recover.

Darwin influenced us to see ecosystems as primarily competitive arenas. In practice, we are now learning that they are reliant on almost as much cooperation as the internal functioning of any organism. It is all this systemic cooperation, despite the superficial visible competition, which enables habitats to be long-standing stable systems, which help to regulate the biosphere. In interfering with the various ecosystems around the world, the challenge that we face is that competition quickly re-establishes itself. It is all that cooperation, whether predation or symbiosis, such as trees communicating through mycelium under the forest floor, which is essential for stability and self-regulation. And that takes much, much longer to become established or recover when we interfere.

Though there is much publicity about our concomitant extermination of other species, we should see ecosystems as whole functional entities. An alternative way of seeing food webs is as neural networks (see Figure 20b), which can be fully understood as cooperative entities. They make up a coherent whole, from which emergent behaviour, such as localised control of the environment arises. It is then meaningless to save a favourite furry or flippered animal without maintaining the habitats of which they are a part.

Saving and preserving ecosystems is not a matter of altruism. It should be understood as entirely selfish. Just as brushing your teeth is an activity that you carry out today with the foresight that failure to do so will come back to bite you at some unforeseen time in the future. Our newfound power over nature comes with the responsibility to recognise that we are masters of our own destiny. We might be able to survive on a very wide range of comestibles. But we are, after all, still dependent on many of those ecosystems to produce the food we need to survive, to maintain regionally stable climatic conditions and to recycle our colossal amounts of waste, such as carbon dioxide. As many an environmentalist will argue, if we continue to damage all these global systems, then the unfavourable consequences will hit us down the line, resolution of which will be much harder than extracting a tooth.

Chapter 18 - Divergence and Convergence

"Are we still evolving?"

Let's return to some unresolved questions:

1) does evolution always operate in forward gear?
2) what are the consequences of Active Cooperation at Level 3?
3) what are the consequences of Passive Cooperation at Level 3?

The Bear Exception?

In digesting the evolutionary process described so far, of organisms climbing the cooperative ladder, the insightful reader might observe various apparent exceptions. By way of example, bears are manifestly solitary creatures. How come they are both omnivorous and some so large?

The suggested evolutionary path indicates that, once a species has learnt to cooperate at Level 1, then the most intense inter-agent competition moves up to Level 2. Groups of agents become the Level 1 competitive entities, and, within those groups, we see Level 2 Active Competition occurring, being competitive growth. And so, generation-on-generation the agents increase in size. This does not prevent a degree of competitive growth from taking place between individuals in species which remain competing at Level 1. But, in those cases, the competition at Level 2 is severely muted because the Level 1 competition dominates. So, whilst there may be a push for enlargement, depending on the habitat, it will take much, much longer for a loner species to grow.

Bears are manifestly solitary creatures, competing at Level 1 for today's lunch. Outside of any mating, they are not very friendly to others of their own kind - or anyone for that matter. When there's a bumper harvest, such as salmon returning to spawn, they congregate together to gorge themselves in advance of the winter – like sea gulls mobbing a source of food. But, just like gulls, as soon as the food source is depleted, they disperse again. Outside of the fish feasting, they keep apart and roam in different types of rainforests, mostly temperate, eating all manner of different things. So, they are omnivores too. What's going on?

If you look back to the bear family tree, you see that their closest relations are seals and walruses. Go back a little further and these all fit into the order Carnivora, which includes wolves. These various other relatives of the bear all express far more cooperative behaviour, forming huddles, colonies, and packs. They all share a common ancestor. The detailed history of wolves and bears, what their earlier common ancestors looked like, is vague. But using DNA, the family tree has been carefully decoded, showing how bears are historically related to those other species and when they forked off.

Following the logic of this construct involving the layering of competition and cooperation, that shared antecedent must have formed groups (Level 1 cooperation (active and passive)), thereby becoming more omnivorous, and thereafter undergoing competitive growth at Level 2, progressing from some much smaller creature to something akin to, let's say, wolf size. So, how come bears are now loners?

Having progressed to becoming both omnivorous and larger within groups, it is not much of a leap to realise that some early canids diverged away from their brethren, perhaps focussing on a coastline, and beginning to eat the occasional fish. Their new environment was less conducive to operating as a pack and so their behaviour reverted to individual competition at Level 1 and they unlearnt their erstwhile sociability. And that’s how they remained thereafter. Operating alone, these early bears turned out to be quite successful and gradually spread throughout the forests of the planet, adapting to their unique habitats. Some did continue competing at Level 2 and their size changed a little further accordingly, such as those in colder places needing to store up enough energy to withstand the sparse winter seasons. Others perhaps shrank, becoming leaner, through Level 2 passive competition. It is, however, the omnivorous nature of many bear subspecies, which is the real clue about their history - that at one time their ancestors must have roamed the landscape in packs.

That species can go backwards as well as forwards up the cooperative ladder is a cautionary tale, which we would be well-advised to take heed.

Sex

When agents learn to cooperate, at whatever level of the cooperative ladder, the inherent competitiveness between individuals does not simply evaporate. Each agent still has its own needs to fulfil and experiences the world around itself from a self-centred perspective, ready to revert to competition if the cooperative system of which it is a part no longer satisfies its perceived requirements.

With Level 1 Active Competition promoting aggression as a successful survival strategy, there will naturally be those who are more and less aggressive. These differences become expressed in Level 1 actively cooperative groups in terms of leaders and followers. Those who are born a little more aggressive will express this in group situations through having stronger opinions about where the group should forage next for food. The rest, seeking to avoid cognitive dissonance, fall into line.

Level 2 Active Competition gives rise to steep hierarchies, with larger and more aggressive agents at the top. These pyramidal systems do not disappear when proper Level 2 Active Cooperation begins to occur. Rather they become moderated through the adoption of group rules and codes of conduct. We can observe this in our own recent history. Compare, by way of example, what it would have been like within a bureaucracy such as the British Army a few hundred years ago relative to that of a modern business. Both are bureaucracies. But the modern business environment is strictly regulated, such that bosses can't shoot employees for failure to carry out instructions. The same applies in the natural kingdom, where we can compare the cultural environment in chimpanzee troops with that experienced by bonobos.

So, what happens at Level 3?

Passive competition at Level 3 involves individuals focussing effort to bring up their own offspring, whereas active competition at Level 3 is expressed in terms of competitive reproduction, producing large numbers of progeny with no active nurture. As with degrees of aggression at Level 1, in a pre-sexual differentiation scenario, where all agents were the same sex, there would presumably be variation in competitive reproduction – some agents replicating more than others.

Reverting to the discussion on cells, a major differentiator between eukaryotes and prokaryotes is the manner in which they replicate. Prokaryotic cells are entirely asexual. They all replicate in the same way. Eukaryotic cells, however, can reproduce both sexually and asexually. And then scaling up to multicellular systems formed from eukaryotic agents, these pretty much universally reproduce sexually (two different sexes coming together).

If eukaryotic cells and thence multicellular systems are ultimately derived from prokaryotic cells, then somewhere along the evolutionary line sexual reproduction must have emerged. Looking to the competitive side of the ladder at Level 3, we see passive competition expressed in terms of intense nurture of the self and offspring contrasted against active competition, where organisms compete to generate vast numbers of progeny. It is these two competing tensions, which then become internalised and expressed in the context of Level 3 cooperation in terms of sexual differentiation - two sexes making up one species.

Except for a few species, males are generally able to sire many babies, producing oodles of sperm (Level 3 active competition), whereas females make far fewer eggs (Level 3 passive competition). Furthermore, the males tend to provide sperm and then skip away with little, if any, on-going responsibility, whereas the females in most species will spend more effort providing for and rearing offspring (even if that just involves providing the energy and nutrients to create a batch of fertilised eggs).

So, the suggestion here is that the appearance of sexual differentiation arose at the same time as cells learnt as multi-agent systems to cooperate actively at Level 3. It represented an assimilation of the heretofore passive and active competition at Level 3. Subsequently, where living things already exhibit sexes, such as multicellular organisms, then this tension becomes further exaggerated through activity differences, such as the man focusing his efforts on building a house and defending a territory (Level 2 - work) while the woman rears the children (Level 3 - nurture).

And Magic …

Cooperation at Level 1 depends on agents within a group sharing and possibly exchanging different quanta of food. Hominid tribes could express both these behaviours. If people take turns foraging, then, when each returns on different days with some produce, they share it out. Exchange would happen when different members of the tribe specialise and go out to forage or hunt on the same day, returning later back to camp to swap some of their bounty - some fish for some apples. Agent level opportunistic acquisition of different food types converts into group level generalisation (the whole group acting as an omnivore), resulting in the species becoming more omnivorous. This might best be termed 'division of sourcing'.

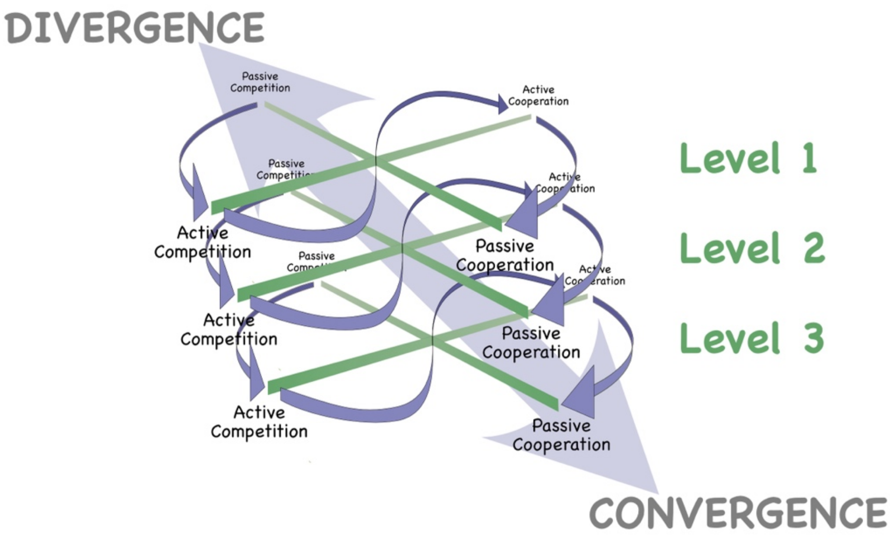
Passive Cooperation at Level 2 reinforces this generalisation, progressing a species from occasional grazing on different food stuffs to becoming reliant on a wider range of nutrient sources. This is imposed because of the emergence of cooperative territoriality, where defending groups find themselves confined to a limited area and must rely on only those foodstuffs available therein. Where a species is not just foraging but also actively securing their future needs through, say, making shelters, then the Passive Cooperation at Level 2 also manifests as division of labour. It is not just man who divides up labour tasks. This is also observed in social insects, where they can be seen to make and defend nests and hives with differentiated forms – workers and soldiers, etc.

Activity focussed on addressing Level 3 needs is not about acquiring or storing energy and nutrients but rather how that energy is subsequently used for long-term benefit - caring for the self, other members of a group and reproduction. Passive Competition corresponds to division of nurture with agents within a group specialising in different activities. This is easiest understood in a human context, where we see various types of nurture - the hairdresser, the chiropodist, the chiropractor, etc. The consequence of this is that individual agents become entirely reliant on the whole group as they can no longer provide entirely for themselves. This results in a cycling of energy around the group or society - you do this for me, I do something for them and they do some other thing back for you. The outcome is a nurturing web, like the notion of a food web in an ecosystem.

Generalised for all types of agents, this step of development enables the emergence of energy and nutrient cycling within whole systems - whether these be between cells in your body, people within a human tribe or in society. These indirect reciprocal interactions result in energy and nutrients becoming trapped in the wider system, as they cycle round and round. The systemic consequence is that whole systems become better able to recycle vital resources and better regulate their internal environment.

For any living system, we can see it as a whole and in terms of its constituent agents - your body and the cells in your body or a human tribe and the humans within. Where the whole endures over time, the component parts are born, live and die. There is therefore scope for those component parts to evolve. This was seen through long eons of evolution as originating bacteria, through climbing the cooperative ladder, eventually became eukaryotic cells. At Level 3, we reach the point at which the whole larger system attains the ability itself to reproduce, such as multi-cellular organisms reproducing or human tribes replicating – producing new functional wholes. In doing so, we can observe an effect, which is the antithesis of Level 1 passive competition (see Figure 21a).

Figure 21a – Divergence to Convergence



Passive cooperation for each of Levels 1, 2 and 3 gives rise to a specialisation within the group - division of sourcing, division of labour and division of nurture. In each case, agents within the group learn to differentiate the roles they play in the furtherance of the whole system. But at Level 3, we see the whole system itself seeking to replicate. To reproduce itself, the whole system needs to create a single template, from which a new whole can be given form. This requires that such new template gains the ability to transform into all these different specialisations. The outcome is convergence and the formation of, what are known as, stem cells, otherwise called undifferentiated cells.

You may have heard about stem cells through reading popular science articles. When an animal or human is conceived through the coming together of a sperm and egg, the very first cell to be created is a zygote. This is the master stem cell. The subsequent series of divisions of this zygote also produce stem cells. As an embryo takes form, then these originating stem cells eventually convert into all those 200 different cellular types in your body - neurons, liver cells, kidney cells, muscles, etc. Scientists are learning to use these amazing stem cells for a variety of treatments including bone marrow transplants and other circumstances, in which new healthy cells need to be grown.

The competing tensions - the requirement for a common template and for the whole to be composed of differentiated parts - gives rise to these magical living things, from which all those possibilities can be unlocked. Nature has learnt through iteration to incorporate into a standardised design the capacity, when triggered, to create diverse forms. A good alternative example is in the ant and termite world, where, using chemical triggers, the same eggs can give rise to at least five different forms - queens, kings, soldiers, workers, and others.

Turning the same logic onto ourselves, we are agents within a wider, largely cooperative, human society. The expectations of the modern synthesis are that there should be gradual divergence of DNA as time goes by. This is that the number of differences in the DNA from one person to another should increase. But, despite there now being some eight billion of us, this is not what seems to be happening. Rather, the diversity of human DNA is surprisingly small. In fact, there is less diversity within our DNA than in the modern African chimpanzee population, despite them numbering only a few hundred thousand.

Our DNA is constructed out of, what are called, base pairs. We have around three billion of these. All human beings have 99.9% the same. The difference of 0.01% therefore amounts to three million. Analysis of DNA across the human population suggests that most of the variation (around 80%, so 2.4 million) occurs between any two randomly picked people, regardless of their origin. Only 6% account for differences between races (say European compared to Eastern Asian). The greatest level of diversity is found within the modern African population.

The normal reason to explain our lack of DNA diversity is to refer to the bottleneck, which is thought to have occurred as Homo Sapiens migrated out of Africa, possibly a couple of hundred thousand years ago. It is suggested that the migrants, who subsequently populated the entire planet, numbered just a few thousand, thereby filtering out much of the genetic diversity left behind in Africa. This may be correct. But it doesn't account for the relative lack of diversity remaining in the African human population compared to our chimpanzee cousins.

If the layered approach to competition and cooperation has any validity, then it suggests that once humans had formed fully-fledged Level 3 cooperative tribes, which could themselves replicate, then from this point forwards there would have been convergence in our DNA, not divergence. As we now form one global society, trading all over the world, moving and mixing and reproducing with each other, then this is increasing. The logical conclusion of this process is that human babies converge towards the same standardised template, becoming the stem cells for civilisation. They are becoming standard adaptable packages, capable of blossoming into a huge variety of different potential skills and attributes, to be able to find useful roles in an increasingly complex and diverse society. As we learn to tinker with our DNA, to eliminate unwanted mutations which cause abnormality or disfunction, then this confluence will only accelerate.

So, yes, we are indeed continuing to evolve but perhaps not how Darwin might have envisaged – as a species, we are instead converging towards a single standard stencil.

What next?

Now that we've addressed some of the most fundamental questions within the life sciences, we can turn our attention to the building blocks that make up those bacteria and eukaryotic cells - atoms and molecules. If the concept of nested processes, giving rise to layered competition and cooperation is valid, then there's no reason why it should stop at the cellular level. Let's now dive into the atomic world, where energy very definitely comes in quanta.