EVOLUTION

HOW DID IT HAPPEN,
if it wasn't by Darwinian means...?

Book One
NON-DARWINIST THEORIES OF EVOLUTION
SEEN IN A MORE MODERN LIGHT

By

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PREFACE

Everything in this book is deeply researched, fully referenced and scientifically supported and gleaned from the most reputable scientific literature and, where possible, from primary (first-hand accounts) historical sources. My journey through this somewhat philosophically-charged field of evolutionary study came about through the dawning realisation that our modern synthesis (Neo-Darwinian) version of biological complexity was not as scientifically grounded as most of us might think (See quote book by this author which will give you an idea of what an increasing number of evolutionary scientists have written on the matter).

To be perfectly honest, I was quite shocked at the current state of our standard theory of evolution. Then of course came the obvious question: How did Evolution happen if it wasn't by Darwinian means? This led me to a deep investigation into the historical background of alternative evolutionary concepts. As a result, I found to my surprise, that there had existed several perfectly sound and sophisticated evolutionary alternatives to the Darwinian dogma.

Furthermore, I discovered that these were, for the most part, historically obscured and yet, were the very ideas that were finding scientific support and verification, particularly in the light of our more modern understanding of biological complexity. Moreover, as my research evolved, these began to converge into what could be described as a not so new: but entirely distinct (alternative) evolutionary synthesis. In other words, evolution could be explained in non-Darwinian terms and it is far too interesting an alternative to keep to myself. Therefore, I thought I would share it with others.

Book One follows each of the main players in the 'not so new' evolutionary synthesis, outlining their theories and presents how these are finding scientific support in the light of our more modern understanding of biological complexity, whereas, the old dinosaurian Neo-Darwinian theory is not. This is only a brief overview, as seen through the research and theories of several scientists of the past and within our current era. These alternative views of evolutionary processes appear to converge into a cohesive whole and begin to offer a rather more sophisticated view of biological processes, than hitherto imagined.

I hope you enjoy!

MariaBrigit

INTRODUCTION

— Denis Noble —

Professor Emeritus and co-Director of Computational Physiology

'PHYSIOLOGY IS ROCKING THE FOUNDATIONS OF BIOLOGY'

... all the central assumptions of the Modern Synthesis (often also called Neo-Darwinism) have been disproven. Moreover, they have been disproven in ways that raise the tantalising prospect of a totally new synthesis.

— Noble (2013) Abstract

Link

This 'tantalising new synthesis' is not perhaps that new, or at least the one that is formulated here, as it follows principles and laws well established within the natural physical sciences (physics, chemistry and astronomy etc) and traditionally employed by developmental biologists/embryologists (the study of development as it applies to evolutionary development). All I will do is to attempt to reformulate these historically obscured concepts in the light of our more modern understanding of the deeper complexities of biological processes. By doing so, a distinct evolutionary synthesis naturally emerges out of the ashes of the old.

In order to present these diverse, but interconnected models, theories and principles of evolutionary complexity, I have divided this book into two main parts. Part One presents these alternatives to our current model of evolution via the main players and their respective ideas. Many of these alternative evolutionary views and the scientists themselves have become historically obscured, if not ridiculed, dismissed and misunderstood due to very specific historical ideological and philosophical issue that require a different and full discussion addressed elsewhere by this present writer (see website here). Therefore, their concepts are presented thematically (not chronologically) and assessed in the light of our more modern understanding of biological complexity. This should give you a background and provide a scientific underpinning to the emerging alternative synthesis. It will also provide the basis to apply these alternatives directly to the fossil record and what we have subsequently discovered regarding the evolutionary past.

Book Two then applies these principles, theories and concepts in the light of more recent discoveries in biology, directly to the fossil record and what emerges is a fascinating overarching and harmonious naturalistic principle that is seemingly universal which, in and of itself, requires our scientific attention. For instance, returning to the subject matter of Book One, some of the older alternative models discuss, using mathematical and knowledge from universal principles that are well-established within fields of science such as physics, the application of universal laws of growth and form to biological systems. For instance, just as much as gravitational forces have shaped our world (and yet we cannot see or touch it, we know it is there by its effects), biological life has seemingly been shaped, formed and made possible by a similar unseen, but measurable force. We can then use this measurement to assess things we cannot measure directly. For example, we don't go up with a massive measuring tape and wrap it around planets and a giant ruler to measure the distance between the planets, we can extrapolate from things that we can measure here on earth and calculated their distance and size.

We are discovering day by day, just how finely tuned and predictable the patterns embedded in our known universe actually are. Any physicist/cosmologist would agree who have assessed the calculations and therefore, it is very difficult to ignore the seemingly Goldie Locks nature of it all (as in the famous children's' story of the little girl with golden hair and the three bears: 'Everything is just right'). In other words, scientists have found that even a slight variation in any of the distances of objects, speeds, quantities or chemical composition and matter would mean that there would be no universe, and of course, life as we know it would not have evolved either. Although the data is culminating to the point where it no longer can be dismissed, it now comes down to what this implies which, certainly opens up a whole philosophical discussion. However, leaving the philosophical issues aside, we can begin to identify the calculable proportions, principles, laws and concepts – the universals, as they relate to biological life. For instance, as biophysicist Stuart Kauffman reveals in his book At Home in the Universe: The Search for the Laws of Self-Organization and Complexity

"...A few deep and beautiful laws may govern the emergence of life and the population of the biosphere"

—Kauffman (1996, 23)

Link

As indicated above, just as a cosmologist can find out things from knowing 'knowable' things, scientists in the past working in developmental/evolutionary biology and those applying such observations to these disciplines were beginning to do the same thing by scaling up or down, the 'knowable' aspects of life and find out otherwise 'unknowable' things, until our Modern Synthesis era took biology in an entirely different direction and dismissed all other alternatives.

Now that we are beginning to understand that our current standard model of evolution is entirely inadequate as a means of describing the deeper complexities of life (see links to publications), we can perhaps begin to revisit the more traditional methods and apply our more recent understanding to old, as yet, unanswered mysteries about evolution. This is a powerful tool, once you begin to ask the right questions. This effectively gives us a virtual time machine (which will have to do until we invent a real one) and allows us to get a glimpse into a large spectrum of life and assess (or reassess), just how it might have evolved until the present day if it wasn't by Darwinian means.

I should note however, that this current assessment of the science behind this distinct approach, doesn't specifically address the origins of life itself (but neither did On the Origin of Species, but a warm pond was noted at some point, and neither does our current model offer a plausible explanation, although it has certainly tried very hard). The reason why I haven't presented the vast amount of updated research in this area here, is because, it would appear that biological origins is actually governed by the principles of a very different and somewhat weird tiny (nano-particle) world that can only be described by quantum theory and this would take another book to deal with this topic. It has its own rules and they are more like what Einstein once described as 'spooky action at a distance'.

Therefore, I will review the most recent evidence on this topic in a later publication entitled 'The Quantum Butterfly Effect and the origins of life" (check out http://diggingupthefuture.com for updates on its progress). Yes, for some reason or other, our known universe would appear to have rules and laws which apply universally. Whence and why these universal arise is perhaps a matter of philosophical discussion and I don't believe that what comes out of such discussion, should inform the way we pursue the science itself. Look where it got us before?

Returning to the bigger world that we can seemingly, see, touch, smell and taste, I believe that all we have to do, is simply follow the rules that apply to these scales of existence, the universals as they have been revealed via the research of many different scientists (present day and historical). This is what I have attempted to do here. I have also followed a diverse range of disciplines that have addressed the deeper issues of biological complexity which seem to all have different, but interlocking pieces of the same evolutionary puzzle. It is only when you bring the seemingly disparate parts together that a whole theory emerges.

Historically, scientists often used a multi-disciplinary approach and sometimes it seems that they had a more overarching view and larger pieces of the puzzle because of their broad approach. However, for the most part, biologists, particularly in our more reductionist era, do not generally appreciate their field being invaded by physicists or mathematicians or any of this type of whole-system and universals type thinking. This is acknowledged by Geoffrey West (a physicist working on biological problems) who highlights the different mindset between biologists for the most part and physicist. It is taken from an interview entitled: 'Yeah, but what about the crayfish?' *(... Where, the title is a reference within the article to how some biologists still show concern about details of animals such as crayfish even after being presented with the deeper complexities of scaling laws and universals*).

A different mind set

"In general," ... "although this was not true of my collaborators, biology tends to be dominated by a certain type of person in the opposite way to physics. They are always looking at the particular, and everything is an exception." ... [West] does not understand how such people can work in science if they do not believe there are such things as universal laws. "If you had biologists working, for example, in nuclear physics you would have someone working on deuterium and then someone else working on helium and they would not realize they were working in the same field."

—Cartlidge (2001 – Physics world)

Link

West and his collaborator Brown are quoted as follows: This is taken from another interview entitled: Of Mice and Elephants: A Matter of Scale:

> *"Physicists tend to look for universals and invariants whereas biologists often get preoccupied with all the variations in nature," Dr. Brown said... Dr. West liked to joke that if Galileo had been a biologist, he would have written volumes cataloging how objects of different shapes fall from the Leaning Tower of Pisa at slightly different velocities. He would not have seen through the distracting details to the underlying truth: if you ignore air resistance, all objects fall at the same rate regardless of their weight.*
>
> *Link*

Continuing on in the same interview article, below is West's concluding remark on some of the criticisms of this type of research which seeks to identify universals within biological systems as well as other man-made systems:

> *Dr. West is not too bothered by these seeming exceptions. The history of physics is replete with cases where an elegant model came up against some recalcitrant data, and the model eventually won.*
>
> *—Johnson (New York Times Jan 12th 1999)*
>
> *Link*

The older and more recent studies of universals as they apply to biology demonstrate that biological systems cannot be reduced to their constituent parts in a Newtonian mechanical and linear way. And contrary to popular belief, Nature is not actually about vying for top-dog position as we have been told. A tree growing in the forest doesn't get too big for its boots and says: "move over buddy! There's not enough light". A snowflake or snow flower doesn't put on one ice-crystal or petal at a time or vie for Top-Dog position.

Everything in nature, no matter how complex, that has been studied thus far, show surprisingly similar scales of underlying simplicity ~ universalities, following predictable patterns and comply with universal laws as proposed by some of our major players in the 'not so new synthesis' and the nuts and bolts of the biological processes identified by several other scientists that begins to give us a very clear insight into how these universals expressed themselves in natural living systems as reviewed throughout this book.

CHAPTER ONE

UNIVERSAL PATTERNS OF LIFE

D'Arcy Wentworth Thompson
(1860 – 1948)

Fig. 1: Photograph of D'Arcy Thompson the Scottish biologist, mathematician and classics scholar and pioneer of mathematical biology (Source: http://www-gap.dcs.st-and.ac.uk/~history/PictDisplay/Thompson_D'Arcy.html)

Thompson was born the year after Darwin published his famous book on 'On the Origin of Species'. D'Arcy Thompson published 'On the Growth and Form' 1917 [Link]. He uses the known processes and principles of the physical sciences of his own era and their tools of explanation to attempt to explain biological processes of development as they may relate to evolution, particularly within one chapter entitled: the theory of transformations. This shows the simple geometrical equations that underlay even the most complex patterns and demonstrates how these diverse formations may be commonly connected, not so much via

Darwinian linear descent, but by laws of growth and form. Essentially, he observed the principles of self similar repeating patterns on different scales of magnitude (we would describe these today as fractal) and he measured them and found that they had predictive and quantifiable proportions which for any mathematician or physicist, is a joy to behold. Moreover, he recognised the universality of these simple constants or invariant qualities throughout the natural world.

Therefore, it wasn't just about pretty patterns and interesting mathematical abstractions, but these had very real applications. It meant that predictions about otherwise unknowable biological complexity could be discovered. Indeed, Thompson's observations have been picked up by NASA scientists who are using his book of life to find extraterrestrial life as seen below. On the NASA website the article is entitled: 'Who Wrote The Book of Life? Picking Up Where D'Arcy Thompson Left Off'

NASA scientists are using Thompson's

biomathematical studies of life forms on Earth to postulate about life forms throughout the universe. There are certain universal conditions that will always affect the shape of a life form, wherever that life may be.

"Everywhere Nature works true to scale, and everything has a proper size accordingly," wrote Thompson. "Cell and tissue, shell and bone, leaf and flower are so many portions of matter, and it is in obedience to the laws of physics that their particles have been moved, moulded and conformed." ... Gravity, for instance, acts on all particles and affects matter cohesion, chemical affinity and body volume. Other influences that are consistent throughout the universe are temperature, pressure, electrical charge and chemistry.

Link

Yes, I noticed that they weren't following Darwin's 'On the Origin of Species' on their cosmic missions. Anyway, D'Arcy Thompson's ideas and concepts are definitely finding more recent scientific verification. Obviously, these universals of growth and form that Thompson and others proposed are powerful generalisations as they can allow us to effectively see into the otherwise unknown. These bigger principles highlight the underlying properties or biological organisms, which can explain in more simple terms, otherwise, seemingly inexplicable complexity.

For instance, he was impressed by the fact that although biological forms differ widely, that the mathematics to describe them remains the same. Does this not give us another means of understanding evolutionary complexity? Thompson didn't just describe and catalogue all the natural patters seen in nature, but explained their simple underlying properties that linked and was common to all. He even had a mathematical description for certain spirals (self-similar patterns) as seen in the form of many shells and applied what he called a logarithmic spiral to these predicable forms. These and many other shapes in nature had the property of never changing its essential shape no matter how large or small, the equation was scaled up or down and still applied. Thompson went further – as these were scalable principles, and from his observations and mathematical descriptions, applied these rules of growth and form to the species and evolutionary complexity.

For instance, he states the following regarding this proposition which he offers as an alternative to the Darwinian view, which at that time was certainly not accepted as dogmatically as it is today. Remember this is the early 20th century prior to the reinstatement of Darwinian theory in its current genetically driven form: (note that protozoa refers to the entire kingdom of animals, and quadrupeds are four-limbed animals).

...for eighty years' study of Darwinian evolution has not taught us how birds descend from reptiles, mammals from earlier quadrupeds, quadrupeds from fishes, nor vertebrates from the invertebrate stock... Our geometrical analogies weigh heavily against Darwin's conception of endless small continuous variations; ...Our argument indicates, if it does not prove, that ... the "higher" protozoa, for instance, may have sprung not from, or through one another, but severally from the simpler forms; or that the worm-type, to take another example, may have come into being again and again.

—D'Arcy Thompson 'On Growth and Form' (1917, 1093-1095).

Link

Further reading See: Thompson, D'Arcy Wentworth (1894). "Some Difficulties of Darwinism". Nature 50: 435 (Link). This type of statement may be the reason why in more recent studies, which actually support many of Thompson's concepts as they apply to biological growth and form, appear to be missing the fundamentals of his theory and its deeper implications. This is exemplified in a recent Harvard paper entitled: 'Scaling and shear transformations capture beak shape variation in Darwin's finches' [Link]. To summarise this article, although they accept his principles of scaling etc to account for as the basis shape and form of beak development in Darwin's finches, but then they proceed to point out that as he obviously didn't understand genetics and his data didn't fit their genetic model, they went on to discuss the evolution of the bird itself by Darwinian means. Throwing out the baby with the bath water comes to mind at this point. What if Thompson's scaling laws were correct and their genetic model wrong? As you will see further on, their genetic models is indeed incorrect.

Now returning to NASA, obviously they don't hold the same views as the Harvard study and now returning to terra firma from his missions in space, let us apply Thompson's concepts fully to evolutionary development and not just to explain something like the beaks of finches, just as Thompson proposed the principles of scull or facial formations of the jaws and ridges, or the shells of marine creatures (spirals) that conformed to the governing principles (universal patterning) of spatial proportion as they could be plotted according to mathematical equations (reproducible by using fractal patterning and ratio equations for spatial arrangements and patterning today), we could perhaps project these principles of growth and form back in time to establish how whole species formed. They are after all, predictable and hold at every scale. Speaking of scales, below is a really simplified illustration of one of Thompson's principal concepts.

Knowing the coordinates on two axes, Thompson was able to work out the third axes as it was on a predictable pattern. In many ways, he was working in 3D space and bending and stretching the flexible grids that always scaled up or down or as he said could be distorted in any number of ways, but the relative order, spatial arrangement and magnitudes would keeps it relative proportions. Since Thompson's time, much research has taken place, particularly within embryological studies, that lend much support to his observations of shape and formation of an organism and how this can be applied to describing species development. For example, the way that these formations of patterns come to be is perhaps best described like a bar magnet can form fields of attraction, or repulsion. We can't see the field, but we know it is there from its effects on iron filings for example.

Indeed, if we had enough iron filings and moved these bar magnets around at different points, we could change, and sculpt these into many different forms, but in the case of biological systems, Nature is the sculptor and she follows predictable universal rules, which are scalable patterns of symmetry and spatial proportions and are all involved in the outcome. The equivalent to the magnetic field in biology is known by its effects, as it cannot be directly seen, is the morphic field and it guides, the patterning and spatial layout of bodies during development.

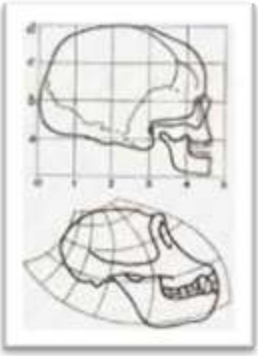

Fig. 2 Transformation of coordinates in ape compared to human skull. Source: 'About D'Arcy' Web site Link

As illustrated above, by transforming the sae basic forms on a highly flexible sheet that stretches and skews in all directions proportionately, this example can emphasise the jaw area in an ape and shrink the brain case, whereas, in a human skull the jaw and front facial region are flattened and miniaturised and the human skull case is enlarged proportionately in comparison. Overall, the difference is superficial and can be explained via a type of morphic field that build up the contours during development.

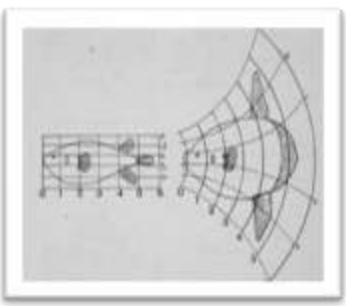

Fig. 3: Transformation of coordinates change the basic shape in every direction proportionally to itself (after D'Arcy Thompson 1917, figs 525-526). Link

On Growth & Form

From this comparison of the gorilla's or chimpanzee's with the human skull we realise that an inherent weakness underlies the anthropologist's method of comparing skulls by reference to a small number of axes...But it is, in the first place, evident that these axes are merely the principal axes of a system of coordinates, and that their restricted and isolated use neglects all that can be learned from the filling in of the rest of the coordinate network"

—D'Arcy Thompson (1917,. 1084)

Link

Another important aspect of Thompson's observations of growth and form was the concept that: a small change at the beginning can lead to a very big change further down the line. This is a well established observation of evolutionary developmental studies which I will review further on. It is also a well known principle in the Chaos theory branch of physics that tries to understand the tendency of systems to become disordered or chaotic and conversely, systems that seem disordered initial, tend to organise themselves. You may have heard of it – it is called the butterfly effect.

This concept came about as a result of trying to study the very unpredictable pattern of the weather. The problem was that when numbers were rounded off and put into a computation machine to project the outcome of the weather, the actual rounding up of numbers rather than using all the smaller numbers after the decimal place was believed to have no effect or a very minimal one to the end result. However, this very minuscule change at the beginning led to wildly different results depending upon the starting conditions. Therefore, it was given the analogy of a butterfly flapping its wings on one continent could have the potential to create a hurricane in another continent further down the line and coined the butterfly effect.

This is a fundamental principle of this current synthesis presented here. This concept applied, means that even a minor change in the conditions of a developing species may and indeed, seems to have had a profound effect upon how it evolves and what it evolves into in the end. This aspect of D'Arcy Thompson's research as well as his general principles regarding growth and development as it relates to an alternative form of evolution of the species is summarised below on the website dedicated to the man and his research:

On Growth & Form

After easily transforming our coordinate diagram of the human skull into a corresponding diagram of ape or of baboon, we may effect a further transformation of man or monkey into dog no less easily; and we are thereby encouraged to believe that any two mammalian skulls may be compared with, or transformed into, one another by this method. There is something, an essential and indispensable something, which is common to them all, something which is the subject of all our transformations, and remains *invariant* (as the mathematicians say) under them all. In these transformations of ours every point may change its place, every line its curvature, every area its magnitude: but on the other hand every point and every line continues to exist, and keeps its relative order and position throughout all distortions and transformations.

—D'Arcy Thompson (1945, .1085)

Link

About D'Arcy

... the dynamic influence of starting conditions lies in the morphology of shells and horns. These are the permanent, non-living, three-dimensional record of a temporary, two-dimensional living state – the base of the horn, or the mantle of the shellfish. D'Arcy Thompson showed that all horn and shell morphologies could be described in simple mathematical terms readily derived from the incremental nature of growth.

... For instance, geometrical rules of packing determine cell arrangements. These need not be specified, but can arise spontaneously. Yet the packing arrangement may be "useful" in minimising the space occupied by the cells, by maximizing cell-cell contacts, by establishing different categories of cells ("inside" versus "outside"), and so on...

Perhaps the most famous images from 'On Growth and Form' are the transformations. D'Arcy showed that gross variation in form between related species could be modeled by the consistent deformation of a sheet.

The consistency of the deformation is the crucial point here: it is obvious that any fish form could be made to look like any other fish form, if it were sketched on a perfectly deformable elastic sheet, and stretched in many directions at once. But D'Arcy Thompson showed that if the sheet were stretched in one particular pattern, then a new species form would be generated. This remarkable and curious observation has not been fully explained even today.

Link

One possible explanation of this profound observation (and in some ways one could say that D'Arcy Thompson anticipated this important concept employed by evolutionary developmental studies today and the fact that his perfectly deformable elastic-type sheet concept is reminiscent of how cells remember surface tension – a memory foam type concept which I will discuss in the following chapter), and that is: an organism appears to develop within a patterning field which shapes and forms the cellular order and timing and ultimate growth according to available resources; resources being in the case of a developing organism, everything that it will ever need to breakdown, process, synthesis and maintain its energy and growth requirements over the course its life time.

If there are more resources to draw upon, then a whole new scale or level of complexity will be initiated following the same process as before, but on a larger scale of size and related complexity. These whole modules of growth and development are predictably scalable ratios corresponding to distribution networks (fractal-like) and their efficiency if we employ some important findings relating to energy use and biological systems carried out more recently as you will see below.

Something Universal is Going on… and D'Arcy Thompson may have been right

D'Arcy Thompson's identification of the simple mathematical equations that underpin the outward complexity of biological life and its scaling principles that somehow shape and form life itself, comes down to 'whole system thinking'. That a change in one part of the system effects the whole, where everything is context dependent. These are common approaches taken within the natural physical sciences where a physicists and/or mathematician's attempts to solve problems of complexity would typically look for the 'invariants' the certainties and measurable properties that can be explained by equations and as these work at every level, they are what is referred to as universals or laws of scale. Thompson pondered this seemingly strange order of nature and noted that the underlying principles of order – were somehow universal and somehow managed to shape and keeps everything as it grew and developed in perfect proportion to itself. This led him to state as detailed above:

"There is something, an essential and indispensable something, which is common to them all". (Link).

Or as we are beginning to establish in more modern times, as stated in an article entitled: 'Of Mice and Elephants: a Matter of Scale' Geoffrey West (the physicist applying his discipline to answer problems regarding biological complexity and like Thompson, finding amazing simplicity and universals common to it all) is quoted as follows:

"Everything around us is scale dependent,"…

"It's woven into the fabric of the universe."…

"It is truly amazing because life is easily the most complex of complex systems,'.... 'But in spite of this, it has this absurdly simple scaling law. Something universal is going on."...

—Johnson (New York Times Jan 12th 1999)

Link

Now although West et al do not question the fundamentals of our current theory of evolution, as they probably, like many don't actually realise there are serious flaws within it, however, the nature of their research certainly lends further support to the older historically obscured concepts of universals and fractal-like systems of growth on every scale of complexity proposed by scientists such as D'Arcy Thompson.

Like the more recent research on scaling laws and universals as highlighted above, D'Arcy Thompson established, as the pioneer of mathematical biology, universals and predictable properties embedded in nature. However, due to historical reasons as noted previously and as I will outline as appropriate to the topic of discussion, as you are well aware of by now, our modern synthesis does not currently approach evolutionary issues from the whole-system perspective. Mainly this is due to the fact that they don't yet realise, for the most part, but this is finally changing some quarters, that as Thompson and many others before and after him point out: the question to how evolutionary unfolded or erupted, and the species arose, is still unanswered.

Furthermore, if the research to try and understand EVOLUTIONARY complexity and origins of the species is not assumed to be underpinned by selection and driven by genetics (mutations for the most part which I will discuss further on), then it is generally not permitted within our current era of biological study. However, if the research is not questioning evolutionary complexity itself and certainly not offering another means to how it occurred, as Thompson, and as you will see further on, others have, and one excepts the basic tenet of Darwinism, then biological complexity is itself allowed to be addressed via other approaches.

This latter situation is therefore exemplified in the research of Geoffrey West and others, as although they are finding amazing universals and scaling laws and are even finding support from people like Richard Dawkins as can be seen in a number of article interviews with West, they naturally default to assuming that this emergent behavior is somehow acted upon by selection etc and of course genetics would have to be defaulted to as well as the principal driver of this evolutionary complexity and finally, they would never think for one moment that there is anything wrong with our current model of direct genetic, mutating basis of common descent.

However, as the record shows, there is a great deal wrong with it which I will certainly address further on as appropriate, which is exactly why we are trying to find alternative in the first place. The principles presented in this part form an important aspect of the newish synthesis. Or I should say: the synthesis that may have emerged naturally if other unfortunate claims had not been so forcibly reinstated. Claims that were never scientifically founded in the first place (see ebook link or paperback link for 'Lamarck and the Sad Tale of the Blind Cave Fish' for more background on this issue).

Anyway, this does not take away from the great research that is emerging in this exciting field of universals, scaling laws, fractal-like networks and explanations for biological complexity that might come down to simple mathematical equations to describe them. However, for the purposes of this present discussion, I am going to scale up and down to the evolutionary level of species formation the findings from the more recent studies by West and others, so as to point to alternative principles for a distinctly different means of developmental evolutionary transformations similar to that proposed by Thompson.

I will therefore attempt to apply the more recent research on scaling laws, invariants and universals to see where it begins to take us. This will only make full sense once I have reviewed all of the other main alternatives for this form of evolutionary development. For instance, Thompson is not alone in his concept of several forms of worms-types that may have emerged repeatedly and the fact that his research clearly indicated that forms emerged (diversified) into many variations from simpler common forms and that all development thereafter, was predicable at every scale if we understood the fundamental type (form) of the earlier (starter) formation.

As I noted above, thanks to the work of physicists like Geoffrey West and others and the application of scaling laws to biological systems and complex systems in general (the physicist applying principles to biological problems) answers many mysteries about otherwise, seemingly mind-boggling aspects of biological complexity, and at the same time points to the surprisingly simple universal principles that underpin such complexity.

It's Literarily a Matter of Scale

The clear identification of the scaling principle as applied to biological metabolism is traditionally associated with Kleiber's law which relates to the seeming universality of metabolism rate to mass of an organism. [Link] It would appear that biological complexity really does have a simple underlying principle within otherwise, seemingly complex organisms and it is just a matter of scale as noted above by West. Kleiber's law, which dates back to the 1930s and the observation that almost universally for animals studied, their metabolic rate broadly scales to the ¾ power of the animals' mass. Max Kleiber (1932). 'Body size and metabolism'. [Link]

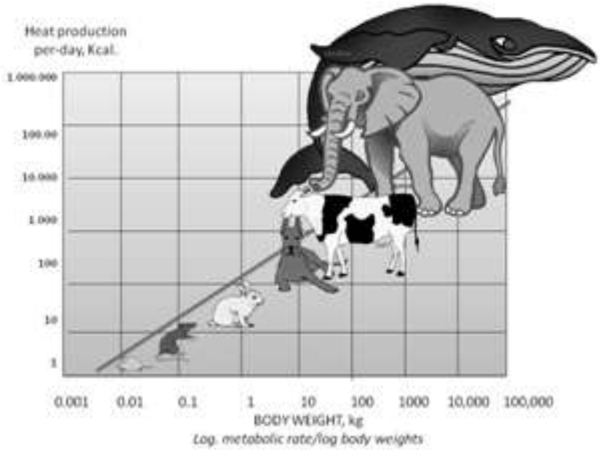

Fig. 4: Idealised metabolic rate to mass/surface area based upon Kleiber's ¾ scaling law. As mammal mass/surface area increases: so does its metabolic rate increase on a scalable gradient slope.

Applying Kleiber's laws in a more modern era has proved rather fruitful and more researchers have added on anything from amoebas to antelopes since his original proposal. Everything really would appear to scale in terms of metabolic rate to mass by factors of predictable magnitude, just as Thompson recognised when he assessed the development patterns of shape and form in a large range of organisms. It is also interesting that Thompson sometimes encountered problems when it came to comparing fundamentally different species and this led him to suggest that there may have been fundamentally different templates, which conformed to their own universal patterning, but these distinct systems could still be understood by more general principles. West and Brown encountered a similar problem which arose when they attempted to apply the same ¾ scaling law established across many animal species to the very different world of plants. But as you will see below, in this case when physicists get it wrong, as they occasionally do: they admit it. In the interview article: 'Of Mice and Elephants: a Matter of Scale', published in the New York Times, the following journey of discovery is described according to the team of physicists/biologists attempting to apply the quarter scaling law:

What emerged closely approximated a so-called fractal network, in which each tiny part is a replica of the whole. Magnify the network of blood vessels in a hand and the image resembles one of an entire circulatory system. And to be as efficient as possible, the network also had to be "area-

preserving." If a branch split into three daughter branches, their cross-sectional areas had to add up to that of the parent branch. This would insure that blood or sap would continue to move at the same speed throughout the organism. The scientists were delighted to see that the model gave rise to three-quarter-power scaling between metabolic rate and body mass. But the system worked only for plants.

"We worked through the model and made clear predictions about mammals," Dr. Brown said, "every single one of which was wrong."

In making the model as simple as possible, the scientists had hoped they could ignore the fact that blood is pumped by the heart in pulses and treat mammals as though they were trees. After studying hydrodynamics, they realized they needed a way to slow the pulsing blood as the vessels got tinier and tinier. These finer parts of the network would not be area-preserving but area-increasing: the cross sections of the daughter branches would add up to a sum greater than the parent branch, spreading the blood over a larger area. After adding these and other complications, they found that the model also predicted three-quarter-power scaling in mammals. Other quarter-power scaling laws also emerged naturally from the equations. Evolution, it seemed, has overcome the natural limitations of simple geometric scaling by developing these very efficient fractal-like webs.

—Johnston (The New York Times dated to Jan 12th 1999)

[Link]

The nature of fractal-like patterning and the rules of growth and development reflect the scaling concepts of D'Arcy Thompson's research. There is seemingly, a common underlying (universal) principle that guides growth and development, no matter what the species (See article outline below):

Mammals have richly branched air tubes, but they are confined to special organs, the lungs. Fish do a similar thing with gills. Trees use their richly dividing branches to supply their leaves with water and pump sugars back from the leaves to the trunk. The 3/4-power law is derived in part from the assumption that mammalian distribution networks are "fractal like"...

[Link]

This begins to reflect Thompson's concept of self-similar and repeating patterns at all scales of complexity and the way that shape and form and patterning and systems – he called networks which appeared to be space filling in a predictable way. This dovetails with Thompson's concept of principles of scale and size correspondences which never changed fundamentally no matter what the size, proportions, plain or scale. Everything remained in proportion to itself and contained the properties of the whole within it. For instance, the following explanation of the above graphic is taken from a paper entitled: 'The origin of allometric scaling laws in biology from genomes to ecosystems: towards a quantitative unifying theory of biological structure and organization' by Geoffrey B. West and James H. Brown.

Introduction

...all organisms share a common structural and functional basis of metabolism at the molecular level. The basic enzymes and reactions are universal, at least across the aerobic eukaryotes. Additional general rules based on first principles determine how this molecular-level metabolism is supplied and regulated at higher levels of organization: from organelles, to cells, to organisms, to ecosystems. The most important of these rules are those relating to the size of the systems, including the body size of the individual organisms, and the temperature at which they operate. Our theory of quarter-power scaling offers a unified conceptual explanation, based on first principles of geometry, biology, physics and chemistry for the size-dependence of the metabolic process. The theory is based on generic properties of the metabolic distribution networks in simplified, idealized organisms.

Link

And continuing on in the interview with West in the New York Times: 'Of Mice and Elephants: a Matter of Scale'...

This relationship seems to hold across the animal kingdom, from shrew to blue whale, and it has since been extended all the way down to single-celled organisms, and possibly within the cells themselves to the internal structures called mitochondria that turn nutrients into energy.

Link

There are several charts in these articles that plot metabolic rate to mass for mammals, and on closer inspection of these and the metabolic rate to mass/surface area from cellular life to primitive amoebas follow this slope (3/4 scaling law) all the way down to the most minuscule animal life forms. It is interesting as everything really does appear to scale in proportion to itself and everything else at predictable factors of magnitude, just as Thompson established the mathematical equations for shape and form, but it is also interesting on its finer grades of scaling, not just the coarse gradient slope of the ¾ power law, even within the same class of animals, show that there is a slightly different scale plotted between male and females of species as seen on some charts.

Furthermore, as noted above, West and others have established these scaling laws for a wide range of phenomenon, from the growth of cities to the fractal-like nature of the communication networks and the growth of corporations; just about anything and everything systems. According to these researchers, it is all about distribution of resources which by their very nature form fractal-like (space-filling) networks. There is definitely something universal going on if, as these scaling factors apply to not just biological systems, but to systems involving anything biological. From small business to big corporate entities and from the rail network to the whole infrastructure that supports big cities that started out as a one horse town, there is a universal growth/evolutionary pattern emerging. And of course biological systems are not that different as they are all about distribution of resources as well.

(See articles worth reviewing to get a feel for this whole concept can be found at following links, http://jeb.biologists.org/content/208/9/1575.full, http://www.cs.unm.edu/~forrest/classes/cs365/readings/Life%27sUniversalScalingLaws.pdf Video on you tube where West explains a great deal on You Tube https://www.youtube.com/watch?v=GoHD1ROPiUc&w=420&h=315)

It is however, important to recognise that these scaling factors are idealised. Real life is a little messier than these charts reflect. D'Arcy Thompson also pointed to this fact, but still the underlying principles and patterns and the fundamental mathematics remain the same no matter how different something might look on the outside. But as noted earlier by West, biologists have all too often missed the bigger picture and underlying and unifying patterns in nature due to getting stuck on the details and mass of variations. These universals therefore begin to give us a great opportunity to apply laws in principle and find out things about Nature's processes that we wouldn't otherwise be able to do.

There is a real potential here to project back in time by applying these scaling principles and try to begin understanding the growth patterns that evolution itself might have followed. For instance, mass of an organism and its relation to everything else would appear to be a fundamental. Mass to metabolic rate is or example one of many aspects of other scalable biological phenomena.

Other predictable scales complying with power laws are heart beats on average throughout the life cycle of an average mouse with scale in the same ratio to that of an elephant. The smaller animal has faster beats, but the scale according to their mass as pointed out in 'Allometric Relations and Scaling Laws for the Cardiovascular System of Mammals' by

Thomas H. Dawson Link (see chart plotting heart rates in mammals. Again, this shows the ¾ power law of scaling.

These charts are beginning to show patterns, not unlike the principle of the pattern embedded in the 'Matryoshka, nested scales of complexity concept of another scaling factor in terms of intrinsic rate, which is really the measurable, predictable and scalable ratio of size/mass of organism in relation to its population growth rate.

In essence, the concept is that small organisms reproduce (multiply/replicate) much faster than larger organisms. Basically, as most of know from common knowledge, a small species like a mouse reproduce very fast compared to larger mammals such as elephants. The intrinsic differences between fundamental species groups of say a large mammal (self-regulating metabolic animals homeothermic) and a virus could be 100,000 times greater in the viruses! Essentially, as we know the rate and mass/size of one organism, we can predict according to size, the proportions or intrinsic rate in this case of any organism. See chart below:

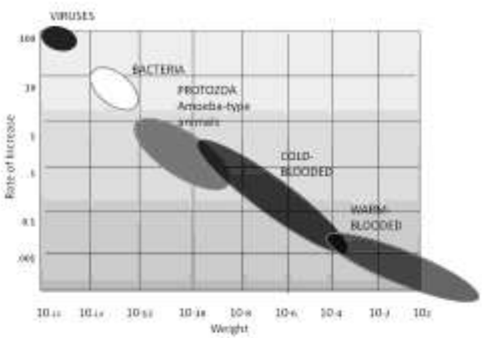

Fig. 5: Idealised chart based upon rate of increase in relation to mass/weight of organism. Note the discrete groupings of fundamental forms/types with only a slight overlap between the more complex animal groups (Diagram based upon figure 11.21 Body size and intrinsic rate of increase - data from Fenchel 1974, Link)

Again, the scaling is very clear where all organisms tend to fall within the predictable slope (gradient) according to their mass/size (fundamental metabolic type) and rate of increase in this case. These are discrete groups of organism where the bacteria are quite distinct from virus organisms and protozoa (small animals that we can't see for the most part) are a whole metabolically distinct group that in turn only overlap slightly with cold-blooded animals such as fish, amphibians, reptiles and these are a discrete, and only slightly overlapping group/type with the warm-blooded mammals and birds. Another simplified chart which plots metabolic rate to mass is illustrated below. Here the discrete groupings of very different organisms are clear as well as the fundamental leaps (discontinuous lines) of metabolic complexity.

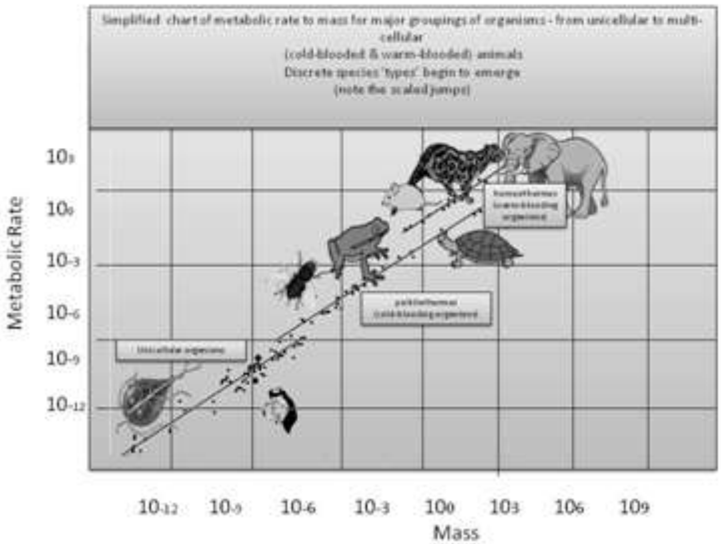

Fig. 6: Simplified chart based upon metabolic rate to mass for diverse organisms ranging from unicellular to cold-blooded invertebrates and vertebrates and from warm-blooded vertebrates. Again note the discrete groupings of fundamental forms/types seemingly nested in scales of complexity. (Chart based upon data from Link and Tatsuo Motokawa, "Elephant's Time, Rat's Time" Link

Recalling that 'type' is the important concept in D'Arcy Thompson's framework, where fundamental forms could diverge into many different varieties leading to what we would call a species, the charts for intrinsic rate for groups of major life-forms from single celled organisms, to cold-blooded and warm-blooded species, clearly cluster into discrete metabolic groups and the leaps of metabolic complexity between each group is worth drawing attention to.

In other words, the neat continuous grade seen exclusively for mammals is not the case when we plot these ratios for organisms with distinct metabolic systems, beyond warm-blooded mammalian forms. This might not seem that amazing at this stage, but it does give us a big clue to evolutionary development. You might notice that if we apply our conventional thinking, for some reason, suddenly and for no apparent reason, species that descended directly from cold-blooded animals that became more mammalian for example (and for some reason, some animals remained cold-blooded) would have to fundamentally change their whole metabolic system, or is this just a pattern of self similarity on different scales of complexity that diverged from a common system of metabolism?

For instance, by employing the power laws of metabolism to mass, intrinsic rate to mass and other things such as heart rate to mass, we wouldn't be top of this evolutionary tree metabolically speaking – elephants and whales are because they are bigger mammals than ourselves. Their mass and the fractal-like networks (space-filling needs) would be scaled up proportionately to make the metabolic system (the heat/energy exchange between the organism and its environment) work at optimum level. But as mammals, we out-rank in complexity of our warm-blooded metabolic system, the cold-blooded (simpler) vertebrates such as lizards and amphibians and in turn they out rank fish and fish outrank insects and so on and so forth, if you want to talk in competitive terms. But, Nature would not appear to be this linearly hierarchical – it is fractal and each part is related to the whole on self-similar scales of complexity and therefore the relationship between the different species may be less literal and not so much about direct common ancestral descent as to do with their use of the same common system (metabolic in this case) in relation to their mass.

Just to reiterate the importance of the discrete fundamental types of species are trying to tell us about evolution, I do find it interesting that a mouse-sized lizard cannot be plotted within the higher scale of metabolism with a mammalian mouse of the same size, but remains fundamentally at the level of metabolic complexity seen in present-day lizard species. Does this mean an invariant? In other words, it is fundamental fixed. Perhaps once a species has become efficient metabolically in that form it can't then do a leap-frog act and fundamentally become a mammalian mouse-sized frog. Maybe this metabolic complexity is a clue to the origin of the level and scale of species complexity in the first place.

I will present one more idealised chart (greatly simplified) to illustrate this idea further. This chart is based again, upon ratios of mass to metabolism. It is prompted by a study of: scaling exponents of fish, amphibians, reptiles, birds and mammals and the results are described by the author's as "significantly heterogeneous" White et al (Abstract 2006). Interestingly, this study disputes the scaling laws as they sometimes show non-universals and it is these differences that are actually quite revealing from the perspective taken here. (Note that West and others have adequately addressed such criticisms of these proposed heterogeneous scales or scales that don't exactly conform to the ¾ power rule).

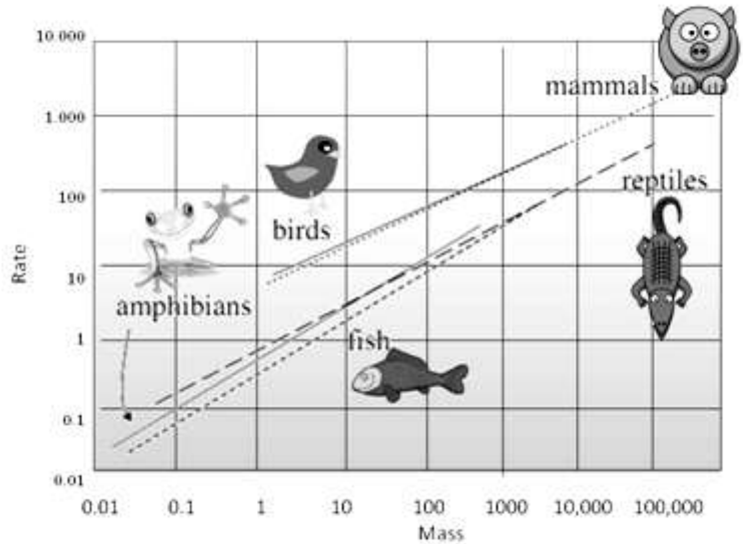

Fig. 7: Idealised chart of the fundamental 'types' of species that scale according to radically distinct metabolism according to their mass within discrete groups. (chart is based on figure 1 from White et al 2006, http://rsbl.royalsocietypublishing.org/content/2/1/125#T1)

Note that birds and mammals are discrete groups that have their own slope distinct from cold-blooded animals as they are more akin based upon warm-blooded metabolism. However, although all the groups follow a scaled slope according to mass and rate of metabolism, each group or type: fish, amphibian, reptile, bird and mammal, can be seen as discrete groups and only overlap slightly with each plotted gradient within their overall group.

In combination, these charts and the scaling principles in general, strongly suggest that the name of the evolutionary game is growth according to resources. It is seemingly about space filling and efficiency at the end of the day. This common metabolic system to mass in exchange with its environment would allow growth on every scale of complexity, providing there would be enough resources to expand the whole system (organisms and their environment). In other words, some organisms would perhaps grow quite large in size compared to say: the microbial level of life, as they developed (their body mass increased perhaps as they could eat more food and gain more energy) and this would in turn increase the complexity of the metabolic system as the space filling requirements (fractal growth) required.

This would work in what is called a positive feedback loop, as the more complex a species would become: the greater degrees of freedom it would have to experience more diverse environments, encounter more exotic experiences and expand and develop further. Growing organisms, like undifferentiated cells, may have developed in different temperatures and chemically distinct environments compared to others and their entire evolutionary trajectory thereafter may have been set in motion just by this slight variation in the early stages.

It could be as Thompson proposes: divergence from fundamental types into all various on the basic theme, always following the spatial proportional rules of that form, only on different scales of complexity and much diversity could come about by a simple variation at the beginning of growth and development. This scenario of course also reflects the concept of a small change at the beginning can cause a widely different outcome in the end. Recall that an organism's shape and form and now seemingly its metabolic system in relation to its mass, can grow and develop, but it will always retain the essential properties and spatial proportions no matter what its size and will always follow the principles of scale. In a sense, species could be similar. They may have arisen and diversified according to these scaling rules and laws of growth and form and space filling and efficiency contingencies may have led to eventually filling every available niche on, in and around, our planet.

We could even begin to talk about metabolic speciation according to and in response to accessible resources and conditions of existence in general as metabolism itself may have evolved in response to growing bodies and obviously other complex cross species interactions and environmental factors such as temperature and chemical interactions of molecules etc. This may have led to species diversification resulting ultimately in an array of life-forms reflecting every level of metabolic complexity and eventually, even to the most sophisticated of them all – the whales, dolphins and elephants, and of course even ourselves. Obviously there is more to evolution than this, but this is our starting principle from which the detail will be filled in.

Recall that flowers don't put on one petal at a time, but whole arrays and then expands according to resources. Imagine a telescope where every part fits neatly into the other part, but all the parts work together to form a whole workable telescope. Well does it not look like Nature operates in a seemingly similar way? Perhaps another way to perhaps think of this over arching scales within scales of complexity, each building upon the same fundamental principle on the previous form, is to try and see it as a whole system, in much the way that Nature actually appears to work.

Evolutionary development therefore, could be described as nested scales of complexity and as a whole system on different levels (akin to the Russian Doll/ Matryoshka Principle). It might help to think more in terms of systems evolving (in this case metabolism) and this allows more advanced forms of life to diverge from this common type or form from which others emerged (think fractal-systems and space-filling concerns – if an organism has reached the full extent of its carrying capacity or its resource distribution networks). This concept is actually supported both in the fossil record and within the most current experimental data as you will see later on in this book when we begin to apply these scaling principles in full, and once we have reviewed all the main alternatives as proposed by several other farsighted scientists (akin to D'Arcy Thompson's approach), the fossil record will start to make a great deal more sense.

Just before moving unto other major players in this emerging and rather un-Darwinian, synthesis, I would like to introduce you to a related aspect of the principle of proportional and predictable scaling at all levels of developmental complexity in general. It is mentioned here as it is actually another scaling law – a repeating pattern on every scale of growth and development and seemingly, it may be applicable (as it is a universal, at least from everything that we have observed growing and developing thus far) to evolutionary development/growth of the species on a much larger scale. Indeed, this proposition encapsulates another important alternative evolutionary model which became historically obscured, that I will discuss in more detail in chapter three. Essentially, this other scaling nested complexity concept is yet another demonstration that: 'something universal going on…' and supports in principle D'Arcy Thompson's recognition of the same.

The Universal Growth/Evolution Curve

West draws attention to yet another fundamental invariant – the universal (or almost universal) growth curve in the following:

…Still largely missing, however, is a theoretical framework for understanding the mechanisms that affect whole-organism growth trajectories. So questions such as why growth curves are almost universally sigmoidal, what controls the final or mature body size, and what affects the allocation of energy and materials to growth and development remain largely unanswered.

http://onlinelibrary.wiley.com/doi/10.1111/j.0269-8463.2004.00857.x/full

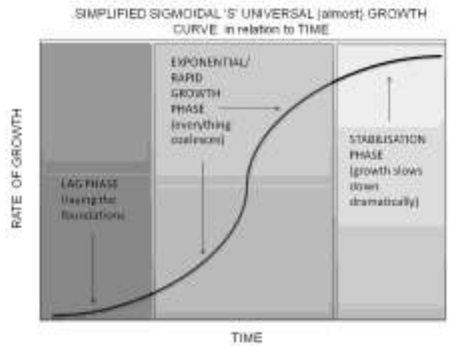

Fig. 8: Idealised chart showing the Sigmoidal growth/evolution over time curve. Left-hand section shows typical 'Lag Phase', the centre section where 'S' (Sigmoidal curve) rises rapidly and is sometimes referred to as the 'Exponential Phase' and finally, the third section (right) is the slow growth/evolutionary stage at the top of the 'S-Curve' which could be described as the 'Stablisation Phase'.

This is seemingly the pattern followed by everything that we have observed and recorded growing or developing, colonising or multiplying in the natural world or systems created by us, follow the Sigmoidal growth pattern as seen in the evolution of internet, computer technology and even social media platform such as Facebook as presented in simplified (idealised) form in the diagrams below. Therefore, it is seemingly ~ universal and we should therefore pay attention to this pattern to see if we can establish how evolution itself evolved (growth and development at another scale and level of complexity. For instance, the things that we can observe and study in real time where, the Signoidal growth pattern is clearly the pattern commencing with a lag phase (fairly slow coalescence of all the necessary aspects needed to create the next level of the whole system), followed by an explosion of growth (an exponential phase) and finally a leveling out of growth and stability with further refinements of the existing system (or organism) – filling out the detail.

This Sigmoidal growth pattern can be seen in the slow development of a woodland, to later (exponential) colonisation of an area and finally, stability

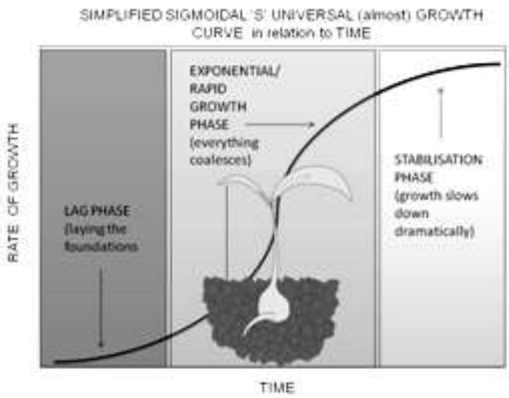

Fig. 9: Sigmoidal growth/evolution over time curve applies to the growth of a seed to a sapling to maturity. Plant biomass is Sigmoidal (See: http://apps.cdfa.ca.gov/frep/docs/N_Uptake.html).

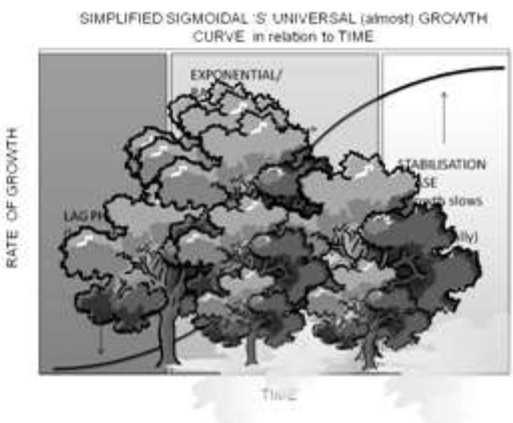

Fig.10: Sigmoidal growth/evolution over time curve applies to the growth of an entire woodland. (See figure 11.5 Exponentlal growth of a colonizing population of Scots pine. Pinus sylvestris. Data from Bennen 1983. http://sky.scnu.edu.cn/life/class/ecology/chapter/Chapter11.htm).

From the seed to the sapling and from the mature plant to the entire colonisation and biomass, follow the same Sigmoidal growth pattern from a lag, exponential and stabilisation stage. The growth of yeast populations and their colonisation are no different, their growth rate is much faster, but this is relative to and proportional to their scale (size).

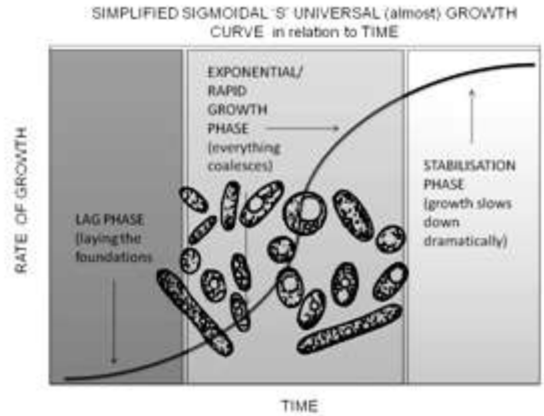

Fig.11: Sigmoidal growth/evolution over time curve applies to the growth of colonies of yeast. as seen in: figure 11.8 Sigmoidal growth by a population of the yeast Saccharomyoces cercvisiac . Data from Gause 1934 http://sky.scnu.edu.cn/life/class/ecology/chapter/Chapter11.htm). Or bacterial colonies is also Sigmoidal, but will rapidly decline in closed system such as a Petrie Dish (See: https://www.premedhq.com/exponential-growth).

Embryological development has a lag phase, quickly followed by an exponential growth phase and stabilisation – it is one again Sigmoidal. And I could fill a page with all the other instances, in other words, biological growth and development and even evolution is predictably Sigmoidal. Basically, as Thompson proposed: at every scale and level, things grow proportionally and in a predictable manner and can therefore be used to calculate otherwise unknown things in nature. This is the beauty of the mathematical formula.

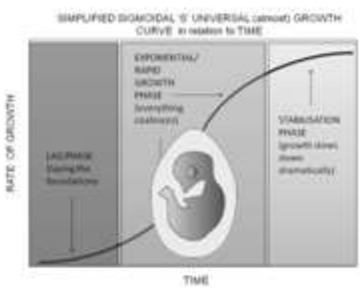

Fig.12: Sigmoidal growth/evolution over time curve applies to the development and growth of an embryo. Then the embryos grew up to develop social media and the internet that also followed a lag phase, an exponential phase and finally reached maturity and stablisation.

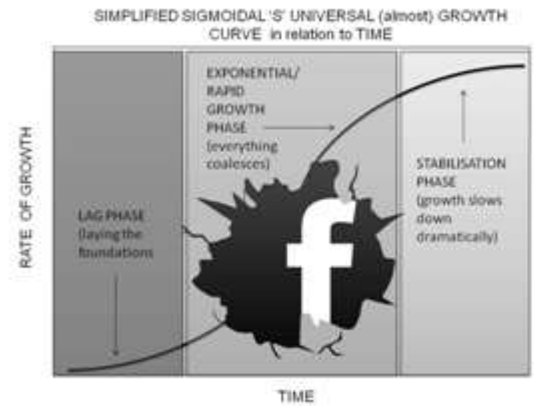

Fig.13: Sigmoidal growth/evolution over time curve applies to the growth of social media: facebook being one well-known example.

What makes the Sigmoidal curve, not only important as a model for seemingly all natural systems that grow and evolve, from the internet, to cities and from broccoli to bacteria, is that is it may give us a very large piece of the evolutionary puzzle, a clue the tempo and pattern of how evolution itself may have occurred, if it wasn't by Darwinian means. I will discuss this application further on in part two in relation to the Cambrian period (the first exponential explosion of complexity as seen in the fossil record). However, just to introduce you to how the Sigmoid growth pattern it corresponds to the fossil record, it is of interest to note that the eruption of complex life (the Cambrian) with little in the way of predecessors (the Pre-Cambrian), but even this is explicable if we apply older obscured theories of evolutionary development as it reflects the Lag Phase, the Exponential Phase and the Stabilisation Phase of the Sigoidal growth curve.

The Sigmoidal curve, as noted above, may also be applied to the individual species types and their evolutionary (development) formation. In other words, scaling laws may apply to the development of organisms in real time just as much as they apply to species evolutionary development in much greater scales of time. The fact that the Sigmoid growth/evolutionary curve is a universal (or almost universal as noted above by West) and as a universal, it is therefore not perhaps surprising that it can be used to predict otherwise unknowns in nature.

The possible reason for all Natural things (and systems created by Natural things) being Sigmoidal, with an initial lag phase, followed by an exponential phase and then stabalisation, may be that Nature is all about efficiency and adaptability according to area/space filling rules in relation to energy concerns and available resources (which is fractally definable/measurable), as the work of West and others suggests, then it could be said that metabolism to mass being in a scalable ratio in relation to each other, directs growth and development in a predicable Sigmoidal pattern because of these concerns. This also begins to give us an insight into why D'Arcy Thompson discovered and proposed what he did when he began to see evolutionary development and complexity in a very un-Darwinian light. In the light of mathematics, predictable patterns and revealed some of its astonishing simplicity and beauty; following predictable patterns that can be explained with equations showing that each portion of the organism/system is a reflection of the greater whole on another scale.

On growth and form

And while I have sought to shew the naturalist how a few mathematical concepts and dynamical principles may help and guide him, I have tried to shew the mathematician a field for his labour - a field which few have entered and no man has explored...For the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty.

Wentworth-Thompson (1917 Epilogue)

[Link]

CHAPTER TWO

THE TURING ENIGMA

Alan Mathison Turing

(1912- 1954)

Fig. 14: British pioneering computer scientist, mathematician, logician and theoretical biologist amongst many other things. Image Source: http://www.telegraph.co.uk/news/science/science-news/9093910/How-did-the-leopard-get-its-spots-Codebreaker-Alan-Turing-was-right-all-along.html

"Codebreaker Alan Turing was right all along"

A. M. Turing (1952) (perhaps better known for his pioneering code cracking abilities during World War II using the ENIGMA), in his publication entitled: The Chemical Basis of Morphogenesis [Link]. I feel that Turing was somehow inspired by Thompson's research and certainly taken by the mathematical beauty of the underlying simplicity of Nature. Where Thompson, explained the underlying simplicity and universality of shape and form – transformations and scaled principles of the formation of the species, Turing showed how cells create these meaningful shapes, forms and transformations of structures in the first place.

Turing's applications to growth and development and variation within biological organisms explores, using theoretical mathematics for example, a model based upon reaction/diffusion of natural chemical/reactions between and within molecules during development and how formula and equations can be used to not only account for many patterns seen in the natural world and cause of their cellular formation, but predict it as well.

Turing's mathematical prediction of chemical signals (morphogens) triggering either an activation signal (diffusion) or a deactivation signal (like a chemical off switch) set up development patterns are finally beginning to find support, particularly as we are refining our means of peering deeper into biological and development processes. His equations therefore, were not just mathematical abstractions, but could help explain the natural development processes that led, for example, to patterning in animals – how the leopard got its spots and how the tiger got its stripes (See article in the Telegraph: How did the leopard get its spots? Codebreaker Alan Turing was right all along) Link

Turing's theory of morphogenesis validated

Scientists from Brandeis University and the University of Pittsburgh show how identical cells differentiate

Alan Turing's accomplishments in computer science are well known, but lesser known is his impact on biology and chemistry. In his only published paper on biology, Turing proposed a theory of morphogenesis, the process by which identical cells differentiate, for example, into an organism with arms and legs, a head and tail...

Turing was the first to offer an explanation of morphogenesis through chemistry. He theorized that identical biological cells differentiate and change shape through a process called intercellular reaction-diffusion. In this model, a system of chemicals react with each other and diffuse across a space — say between cells in an embryo. These chemical reactions need an inhibitory agent, to suppress the reaction, and an excitatory agent, to activate the reaction. This chemical reaction, diffused across an embryo, will create patterns of chemically different cells.

—Burrows (2014)

Link

For Video presentation of Turing's theory and how it is being supported today see: Prof. Philip Maini: Turing's Theory of Developmental Pattern Formation Link. For example, Turing's model helps to explain why cells (that don't know what they are going to be when they grow up), with the identical genes, can differentiate and become all manner of bone, skin, organ cells. Below is a recent example of an experiment and its results which the researchers found rather puzzling, but by understanding that development and its context is inseparable it would be perfectly explicable. In the excerpt below, you will not only see why environment is so important during early cellular development, but it also illustrates how we need to start thinking beyond the Petrie dish and begin applying models such as developed by Turing. The study is taken from the University of Wisconsin-Madison News website and article entitled: 'In directing stem cells, study shows context matters':

Figuring out how blank slate stem cells decide

which kind of cell they want to be when they grow up — a muscle cell, a bone cell, a neuron —

has been no small task for science. Human pluripotent stem cells, the undifferentiated cells that have the potential to become any of the 220 types of cells in the body, are influenced in the lab dish by the cocktail of chemical factors and proteins upon which they are grown and nurtured. Depending on the combination of factors used in a culture, the cells can be coaxed to become specific types of cells.... To fully explore the idea that surface matters to a stem cell, Kiessling's group created gels of different hardness to mimic muscle, liver and brain tissues. The study sought to test whether the surface alone, absent any added soluble factors to influence cell fate decisions, can have an effect on differentiation.

Results, according to Kiessling, showed that a soft, brain tissue-like surface, independent of any soluble factors, was catalyst enough to direct cells to become neurons, the large elaborate cells that make up the central nervous system. Stiffer surfaces favored the stem cell state. "We didn't change anything but switch from a hard surface to a soft surface," Kiessling says. "They all started looking like neurons. It was stunning to me that the surface had such a profound effect."

- Devitt (Sept. 8, 2014)

Link

The key to understanding the above experiment is that cells actually have memory. Think of memory foam; at a nano-scale cells can do something similar. It is an inherited memory that is carried within your cells and operates above the genes – hence, it is referred to as 'epi' meaning above, followed by 'genetics', which should be self explanatory. For instance, on the Genetic Science Learning Centre website, under the heading: The Epigenome learns from its experiences, they state the following:

Epigenetic tags act as a kind of cellular memory. A cell's epigenetic profile -- a collection of tags that tell genes whether to be on or off -- is the sum of the signals it has received during its lifetime.

Link

Furthermore, these markers or tags are bio-chemical. Now when you add the soluble chemical switches externally to the cells environment, which Turing identified and are normally within the development environment of these differentiating cells (or Petrie dish) then you would trigger the sensible assembly of a whole organism, not just cells that would act like other particular cells because of the hardness of softness of the surface they differentiate in. You can perhaps begin to imagine how cells have learned from their environments throughout their evolutionary experience and indeed become very adept at remembering what to be when they grow up into bigger species.

Epigenetics is very profound when applied to evolutionary processes, but it is no less profound than what Turing's research. As you can imagine, epigenetics and environment are intimately linked, but the chemistry involved and its mathematical equations that Turing provided that cracked the real code that has helped us to decipher actual biological complexity. This code can help us understand evolution itself. As Turing's theory relates to the patterning and formation of cells, and as everything 'living' is made up of cells, perhaps therefore it would make sense to pay more attention to his theory and begin applying these mathematically predictable ordering patterns of cells, particularly in the light of our emerging understanding of epigenetics and then we may start understanding another integral piece of the evolutionary puzzle.

CHAPTER THREE

EMBRYONIC DEVELOPMENT EQUALS EVOLUTION – PRINCIPLES OF SHAPE AND FORM

Fig.15: Source: Wikimedia CC.

Von Baer

(1792 – 1876)

Karl Ernst, Ritter von Baer -Prussian-Estonian embryologist

Von Baer proposed a theory regarding cellular organisms (embryos) and by rewinding its developmental stages, their evolutionary species developmental stages could be inferred. Obviously, Von Baer's research was in a pre-genetic era, but his principles are highly pertinent nevertheless to our current discussion.

1828

~ Von Baer ~

~ Embryo Project Encyclopedia ~ 'Karl Ernst von Baer's Laws of Embryology'

In 1828, while working at the University of Königsberg in Königsberg, Germany, Karl Ernst von Baer proposed four laws of animal development, von Baer discusses the embryos of humans, fish and chicks, all of which look similar to each other in the early stages of their development.

As they grow, however, they look increasingly different from one another. The embryo of one species never resembles the adult of another species. Instead of recapitulating other animals' adult forms, von Baer's third law theorized that animal embryos diverge from one or a few shared embryonic forms. The fourth law states that the stages of development in more complex animals never represent the adult stages of less complex animals; they resemble only the embryos of less complex animals.

... Von Baer's second law states that embryos develop from a uniform and noncomplex structure into an increasingly complicated and diverse organism. For example, a defining and general characteristic of vertebrates is the vertebral column.

This feature appears early in the embryonic development of vertebrates. However, other features that are more specific to groups within vertebrates, such as fur on mammals or scales on reptiles, form in a later developmental stage. Von Baer argued that this evidence supporting epigenetic development rather than development from preformed structures.

He concluded from the first two laws that development occurs through epigenesis, when the complex form of an animal arises gradually from unformed material during development.

— Barnes (2013) Introduction

Link

For example, as discussed above, just as the cells know what to be when they grow up (differentiate) into bone, skin, tissue cells etc, cannot be explained via genetics alone, as the cells contain the same genetic code (they would all be the same – clones of each other), well, similarly, as all organisms (plants and animals) are essentially highly coordinated colony of cells, genetics cannot explain the differentiation of the same genetic species looking and acting very differently depending upon its development stage as exemplified in metamorphosing animals. Take for example, a butterfly/moth (a flying insect) and its primitive or developmentally immature form – a caterpillar.

See author's publication 'The Epigenetic Caterpillar: An Alternative to the Neo-Darwinian view of the Peppered Moth Phenomenon' or the e-book version The book should help explain how the same organism/species with the same genome and genes that code for proteins can look and act so differently according to its developmental stage. This book therefore uses the analogy of the caterpillar (juvenile form) and a butterfly or moth (its adult form) with the same genome/genes that look completely different depending upon their developmental stage to illustrate this very important evolutionary concept involving epigenetics (which operate above the genes but ultimately control the expression of existing genes and is essentially an environmentally-driving adaptation process inbuilt within all organisms) – hence, the main title of the book is the Epigenetic Caterpillar.

It is all about how these genes are expressed or not, and to what degree (epigenetically), that makes the difference to whether an insect looks and acts like a sluggy creature (a caterpillar) or looks and acts like a flying insect. This book also presents the evidence for epigenetic speciation (how species change in real time to adapt to their conditions and environment which is not explicable by Neo-Darwinian/genetic mutation and selection means and therefore offers an alternative interpretation (an epigenetic one) to the famous peppered moths story – a much cited case of apparently Darwinian evolution in action – but it on closer investigation, the science is sadly lacking to support this claim.

Therefore, we have to reflect upon the previous discussion about the epigenetic memory and environment/surface that cells develop in directs and controls the variation of form bounded by the conditions of growth and form (universal scaling principles) and this principle also directs, shapes and form multicellular organisms and is fully applicable (on a more complex scale) to species formation in the past. Cellular, embryological and species development are in principle the same processes, only on different scales of complexity and from cellular and embryological processes that we can observe in real-time, we can infer how evolution of the species may have occurred. This is in essence, what Von Baer suggested. Below is an excerpt regarding Von Baer's Laws:

Von Baer described his laws of embryology in both editions of his book 'Über Entwickelungsgeschichte der Thiere' [On the Development of Animals], published in 1828 and 1837. In this work, von Baer reviewed existing information on the development of vertebrates. He used the information in this review to extrapolate his laws. These laws, translated by Thomas Henry Huxley in Scientific Memoirs are verbatim as follows:

the more general characters of a large group appear earlier in the embryo than the more special characters. From the most general forms the less general are developed, and so on, until finally the most special arises. Every embryo of a given animal form, instead of passing through the other forms, rather becomes separated from them. Fundamentally, therefore, the embryo of a higher form never resembles any other form, but only its embryo.

Link

You might recall that this differentiation of forms from generalist (generic) types was also noted by D'Arcy Thompson who viewed evolution from several distinct forms rather than a single common ancestral position. According to the research of Elizabeth Barnes (2014) from the Arizona State University, Center for Biology and Society working on the Embryo Project Encyclopedia, Von Baer's pre-Darwinian theory was taken seriously before and during Darwin's own time and indeed, was considered pertinent by Darwin himself. Von Baer did not adhere to direct linear common descent and instead believed that there may have been several independent origins and that the species went from the generalist (shared common condition) to more divergent and specialised forms as they were shaped by their environments (as a developing organism is shaped by its internal environment) during species development. In essence, Von Baer's laws attempted to scale up developmental processes of an organism (from egg to cells to embryo to full development) as a way to explain development of the species – evolution.

Again, according to Barnes' (2014) assessment of the history, Von Baer's model was somewhat misunderstood in its finer details and became historically obscured, in large part due to the fact that it became overshadowed by Haeckel's embryonic similarity charts across many different species – this ended up being abandoned as they were just a bit exaggerated and the result is that Von Baer's more subtle and less direct common descent model from several different origins fell into obscurity. Most of us have heard of Ernst Haeckel and his famous – now infamous, drawings of different animal embryo drawings, still used in some biology text books today? Well, only seven years after Darwin wrote 'Origin of Species', as noted on the Embryo Project Encyclopedia website, Von Baer's laws ran into Haeckel's recapitulation theory known as biogenetic law. Ernst Haeckel's Biogenetic Law (1866) and below is an excerpt which should give you some historical context:

The biogenetic law is a theory of development and evolution proposed by Ernst Haeckel in Germany in the 1860s. It is one of several recapitulation theories, which posit that the stages of development for an animal embryo are the same as other animals' adult stages or forms. Commonly stated as ontogeny recapitulates phylogeny, the biogenetic law theorizes that the stages an animal embryo undergoes during development are a chronological replay of that species' past evolutionary forms.

Link

— "the Biogenetic Law" "Ontogeny recapitulates phylogeny."

...von Baer did not accept that all species shared a common ancestor. Despite von Baer's objections to Haeckel's biogenetic law and recapitulation in general, the biogenetic law persisted in biology until the turn of the twentieth century when new experimental and comparative evidence rendered it untenable.

Link

Basically, even though Haeckel's theory was dismissed, his concept that was fundamentally distinct from Von Baer's, was more akin in principle to the newer modified version of the Darwinian model. This model, instead of saying that we descended directly from fish, now stated that we descended from fish-like (fishy-pod) ancestors. And all other ancestors are perceived in this linear pattern like a tree and the tree has become molecular and presumes a branching off into lineages to form the different species by passing on only their genetics and acted upon by natural conditions of existence (selection), where the less weak varieties of gene-pools (modelled in hyperspace) tend to be the best survivors. So it didn't matter that Haeckel was a little over artistic in his representations or literal in his concept of linear descent, for by this time, the Neo-Darwinists had their own version of linear descent which was very far removed from Von Baer's laws.

Below is a brief overview of how De Baer's laws are becoming more relevant in the light of our more modern understanding.

With advances in multiple fields, including paleontology, cladistics, phylogenetics, genomics, and cell and developmental biology, it is now possible to examine carefully the significance of von Baer's *law and its predictions...185 years after von Baer's law was first formulated, its main concepts after proper refurbishing remain surprisingly relevant in revealing the fundamentals of the evolution–development connection, and suggest that their explanation should become the focus of renewed research.*

Link

Another notable aspect of Von Baer's theory that is beginning to receive scientific support is the idea of going from the more primitive and undeveloped generalist organism to the more specialist species form. This concept is given clear support when we review for instance, the research carried out such as those studying brain development in vertebrates as highlighted in the work of A.B. Butler, a Professor Emerita (retired) in the Molecular Neuroscience Department in the Krasnow Institute for Advanced Study. The quotes below are taken from 'Evolution of Vertebrate Brains':

'EVOLUTION OF VERTEBRATE BRAINS'

....The simplistic ... concept of evolution ranks organisms on an ascending scale that is presumed to reflect evolutionary history ... as in fish-to-frog-to-rat-to-cat-to monkey-to-human. While this concept is unfortunately widely and deeply embedded in the public consciousness, it is completely unsupported by the massive amount of data on evolution, not only for the brain but for all characters across the board.

...That brain enlargement and elaboration has occurred four times independently presents a very different reality of how brain evolution has operated than is perceived in the widely held folk-belief...

Butler (2009, 57)

Link

... reptiles did not give rise to mammals any more than mammals gave rise to reptiles. In regard to embryological development, it likewise generally proceeds from the general (common ancestral features) to the specific (specializations of the taxon)... What is clearly established is that all taxa have their own specializations. Each taxon has a mix of primitive features.

Butler (2009, 64)

[*Link*]

Basically, this brain study, and indeed many other studies, strongly supports the concept that species converge on ancestral features (shared ancestral condition) and then, later become specialists. This begins to give us an alternative, less literal form of evolutionary development. Further support for Von Baer's laws can be seen below in the form of a more recent model employed by the EVO-DEVO field of research. To help visualise this model below is an illustration, and although it is rather cartoonish and over idealised to say the least, it does illustrate the principle very well. The hourglass model clearly shows a convergence on a shared ancestral condition and later a diversity of many forms from a similar developmental (or ancestral) condition; going from the generalist to the specialist via diversification from a common body plan.

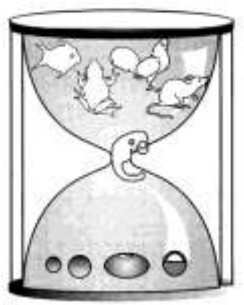

Fig. 16 Source: cartoon illustration of the hourglass developmental model from Richardson et al. 1998

The following abstract from an evolutionary developmental science paper discusses the hourglass model and how more recent support for it corresponds well with aspects of Von-Baer's principles. ***(embryogenesis means the origin of the embryo and phylotypic means the phylo type where phylo refers to the shape and form of an organism)***

Abstract

The "developmental hourglass" describes a pattern of increasing morphological divergence towards earlier and later embryonic development, separated by a period of significant conservation across distant species (the "phylotypic stage")

Introduction

The evolutionary mechanism of conservation during embryogenesis, and its connection to the gene regulatory networks that control development, are fundamental questions in systems biology... Several models have been presented in the context of morphological, molecular, and genetic developmental patterns. The most widely discussed model is the "developmental hourglass", which places the strongest conservation across species in the "phylotypic stage". The first observations supporting the hourglass model go back to von Baer when he noticed that there exists a mid-developmental stage in which embryos of different animals look similar. On the other hand, the "developmental funnel" model of conservation predicts increasing diversification as development progresses...

Link

The divergent characters and variation of these species are the distracting details that most of us get bogged down with. Recall that if we view these organisms as fundamental types (generic forms) as seen in their underlying metabolic complexity to mass according to their major groupings (unicellular organisms, amoeba-types, invertebrates of cold-blooded types and warm-blooded mammalians and birds etc) then, we can try and identify the unifying principles that guide their development and form during embryological development and try and apply this principle to their evolutionary (species) development. We could therefore infer that evolutionary development of the species went through a similar (bottleneck) hourglass type of development as they were going from the diverse generalists to the more specialised and varied forms.

As discussed in chapter one, the concept of the underlying similarity of forms as being nested scales of complexity where, the great variations expressed outwardly by these forms, is analogous to the Matryoshka dolls. And as these nested sets are often painted colourfully in varying detail as their surface area increases, underneath this thin veneer they are all fundamentally sculpted into the same shape and form on graded scales from the same material - wood. It is just that with natural systems, Nature is the sculptor. You will hopefully begin to see how Nature does this as these chapters unfold.

This concept of environment shaping the species has unfortunately been overshadowed by the gene-driven view of evolutionary change ever since the Neo-Darwinists came to promote this view in the earlier part of the 20th century. This ultimately impacted upon the whole field of embryological evolutionary development studies carried on after Von Baer's time. This more modern field is often referred to as EVO-DEVO. This field became heavily marginalised within the framework of our modern evolutionary synthesis. But today we do know that environmental conditions, whether this be the internal environment of a developing organism, or the proposed evolutionary environment of a developing species, these overriding forces do appear to ultimately drive, shape, and, form biological complexity and evolution itself.

The following article summarises the importance of environment during development below, but unfortunately, as much as this more modern theory of synergy promotes and supports the more traditional application of principles of the more physical sciences and deals with whole systems thinking (the whole organism within the context of its evolutionary environment) – hence the concept of synergy, it still defaults to the assumption of linear descent and the old selection basis of evolution.

THE ROLE OF SYNERGY IN THE EVOLUTION OF LIVING SYSTEMS

... the "ghost in the machine"--to borrow the term popularized by the novelist/polymath Arthur Koestler (1967) – is that much of the work in the systems sciences over the years, especially with regard to living systems, has lacked an evolutionary perspective. For instance, it is well understood in evolutionary biology that the interactions between an organism and its environment(s) shape the very character of the "system" over time, including its development, its viability, its longevity and its reproductive success, and that biological causation is inescapably interactional.

Corning (2014, 6)

This environmental driver of evolutionary/developmental processes and its principles which Von Baer certainly adhered to was further developed by embryologists, but this field of evolutionary development did not play a significant role in our modern evolutionary thinking, and maybe this is why the synergy theory points out that systems science have lacked an evolutionary perspective. In other words, there was no modern theory of evolutionary development to work with for historical reasons gone into elsewhere, which was not seen to be exclusively genetically-driven. This is due to the fact that genes and genetics became the all-encompassing explanation for all variation and adaptation as highlighted by Gilbert et al 1996 (Link)

However, the environmentally-driven thinking, beyond the genetically-driven view of evolution (our modern synthesis) and its application has been well understood for many decades now, particularly as a result of study embryological development as you are perhaps beginning to see. For instance, below is a quote which should give you a little historical insight into how embryologists viewed the gene-centred form of Neo-Darwinian evolution the time of the formation of the Modern Synthesis. It is taken from a paper entitled: 'Resynthesizing Evolutionary and Developmental Biology' by Scott F. Gilbert et al.

"Embryologists... saw genetics as "no more intellectual than...a game of cards." Certainly, most embryologists did not feel that they needed to take genes seriously...Genes are not mentioned in most of the contemporary embryology texts (including Spemann, 1938), and Harrison (1937) could ask how the geneticists could possibly say that genes controlled development when they could not explain how identical genes in each cell created different cell types and when they could not point to any examples of genes being active in early development. Genes could determine the number of bristles on a fly's back, but they could not determine how a fly constructed its back in the first place...

Gilbert et al (1996, 361)

http://www.evolbiol.ru/large_files/gilbert.pdf

These more embryonic and non-genetic based insights into evolutionary development were definitely going in the right direction in their thinking and that was within a genetic era when genes and inheritance were relatively well understood. These embryologists, just as Von Baer's laws and principles were based upon observed phenomenon, clearly understood that organisms were not genetically pre-formed as they developed according to their internal bio-chemical environment. The organisms/species were not pre-programmed from the beginning in a preformed way and then simply grew into whatever they are to become, no more than cells containing the same genetics in their nucleus differentiate into completely different organs and systems within the body.

'Does evolutionary theory need a rethink?'

We hold that organisms are constructed in development, not simply 'programmed' to develop by genes. Living things do not evolve to fit into pre-existing environments, but co-construct and coevolve with their environments, in the process changing the structure of ecosystems. The number of biologists calling for change in how evolution is conceptualized is growing rapidly. Strong support comes from allied disciplines, particularly developmental biology, but also genomics, epigenetics, ecology and social science...

Laland et al. in ('Nature' 8th October 2014)

Link

In modern terms, the Neo-Darwinian model adheres to pre-formation in terms of believing that all an organism requires throughout its life and during development, is coded within the genes. Epigenetics/morphogenesis is the exact opposite to this concept. Many scientists, like Von Baer, even the later ones who also had an understanding of genetics, (mostly due to their own experimental observations) believed that an organism develops according to environmentally driven epigenetic/epigenesis processes during development.

Employing De Baer's principles and laws, therefore, De Baer specifically proposed that these epigenetic processes would also apply to evolutionary development of a species, where organisms were shaped as they developed according to their environmental experience. De Baer stressed the importance of the environment as a driver of evolutionary change and also rejected the strict sense of common ancestry as seen in the article below. Again, this information is taken from the Embryo Project Website which reiterates the concept of going from the generalist to the specialist as proposed from the data gleaned from the vertebrate brain study by Butler above and embedded within Von Baer's laws:

Von Baer's first law states that the general characters of an animal group appear earlier in the embryo than the specialized characters do, which contradicted preformationist theories. Von Baer's second law states that embryos develop from a uniform and noncomplex structure into an increasingly complicated and diverse organism. ... Von Baer argued that this evidence support[ed] epigenetic development rather than development from preformed structures. He concluded from the first two laws that development occurs through epigenesis, when the complex form of an animal arises gradually from unformed material during development.

Von Baer used the third and fourth laws to counter the recapitulation theories of [others] which became increasingly popular in Europe throughout the eighteenth and nineteenth centuries.

Von Baer's second law states that embryos develop from a uniform and noncomplex structure into an increasingly complicated and diverse organism.

https://embryo.asu.edu/pages/karl-ernst-von-baers-laws-embryology#sthash.9o6GySax.dpuf

Von Baer's laws along with the whole field of environmentally-driven evolutionary development (epigenetics) is finding very strong support in the scientific literature and when we apply Von Baer's laws to the actual fossil record, it really does begin to make a lot more sense. This gains even more explanatory power when we combine the concepts of growth and scaling laws, and alternative views of evolution held by D'Arcy Thompson and supported by Alan Turing's concept of morphogenesis.

By reviewing these theories collectively, it does indeed seem that evolution has gone from the primitive (less-defined and almost experimental, to the more complex and diverse) via natural environmental and molecular processes of increased specialist adaptations to dynamic environments, each stage builds upon the earlier systems of life and later refines them. The only way this can happen is via subtle molecular forces that shape and form organisms at a cellular/molecular level during development, and as the record clearly shows, and as you will see after further reading, epigenetic systems do indeed have the power to change organisms in response to their environment, rather dramatically and rapidly.

This brings us to name that is synonymous with epigenetics: Jean Baptiste Lamarck, but again like Von Baer's concepts of evolution, these were developed within a pre-genetic age, but are being confirmed and supported by our most up to date studies that have explored the nature of genetics and molecular biology in general.

CHAPTER FOUR

EPIGENETIC EVOLUTION

Fig. 17: Portrait by Jules Pizzetta (1893) [Public Domain via Wikimedia Common]

Jean-Baptiste Lamarck
(1744-1829)

The history of the concept of epigenetics (non-preformation) really begins, in a pre-genetic age and was formulated into a comprehensive evolutionary theory by Jean-Baptiste Lamarck, perhaps best known for his concept of acquired characteristics, but there is more to his theory and even this concept has been frequently misunderstood. Lamarck's theory goes back to over 200 years and even Charles Darwin began to take seriously, eventually as you will see below. Lamarck's evolutionary principles have virtually become synonymous with epigenetic inheritance (acquired characteristics) which is revealed in a number of recent studies and the growing realisation amongst many scientists that epigenetic processes triggered by environmental factors can, do, and have in the past, had a profound impact upon the formation of the species itself is beginning to mirror quite closely what Lamarck had proposed over two centuries earlier within a pre-genetic age. Lamarckian principles were updated sometime later and several very interesting studies began to emerge demonstrating epigenetic type evolution. Lamarckian principles and the term epigenetics is first used in 1907 in a publication by Jordan (ref). Therefore, epigenetics is not a new concept or field of research, but many mainstream articles believe it is a new concept. Again this is to do with historical issues that need to be readdressed which I have dealt with elsewhere (See below).

These epigenetic principles of evolution and the extrapolation of present day development to evolution of the species on different scales are essentially non-preformationist view of evolution (everything required for an organism's or a species development, is not preformed in the genes). This concept is of course the model that Von Baer was essentially using as discussed above. Epigenetics is synonymous with environmentally-driven evolution Lamarckian type acquired characteristics and the story of how he got written out of the history books is a whole topic in itself. You can read more about Lamarck, Darwin's own Lamarckian views on evolution and the very different version used by our modern synthesis by checking out these author links Lamarckian (epigenetic) type evolution is being vindicated as seen in the following article entitled: Lamarckian Evolution confirmed 200 years later in Epigenetic studies in: MIT Technology Review: 'A Comeback for Lamarckian Evolution'

MIT article

Lamarckian Evolution's comeback

Two new studies show that the effects of a mother's early environment can be passed on to the next generation. The findings provide support for a 200-year-old theory of evolution that has been largely dismissed: Lamarckian evolution, which states that acquired characteristics can be passed on to offspring.

...

In contrast to natural selection, in which organisms that are born well adapted to their environment survive and reproduce, passing down those successful traits, Lamarckian evolution suggests that animals can develop adaptive traits, such as better memory, during their lifetimes, and pass on those traits to their offspring. The latter theory was largely abandoned as Darwin's, and later Mendel's, theories took hold. But the concept of Lamarckian inheritance has made a comeback in recent years, as scientists learn more about epigenetics.

Singer (Feb 4th 2009)

Link

The Guardian

The Epigenetics Revolution by Nessa Carey – review

"A book that would have had Darwin swooning"

So far, this is instructive and highly promising for medical research, but epigenetics finally reaches that "everything you've been told is wrong" moment when it claims that some epigenetic changes are *so long-lasting they cover several generations: they can be inherited. This flouts one of biology's most cherished dogmas – taught to all students – namely that changes acquired during life cannot be passed on – the heresy of Lamarckism. But the evidence that this can occur in some cases appears to be growing.*

Peter Forbes

Friday 19 August 2011

Link

Below are a couple of very helpful video links which should help explain the misconceptions surrounding Lamarckian type evolution and the profound implications for evolution when we apply Lamarckian/epigenetic or non-gene-centred thinking to evolution.

'Who was Lamarck? And what did he think?' on Turner channel at YOU TUBE (a short and to the point myth-dispelling video presented by a scientist looking at what Lamarck actually proposed as opposed to what we think he actually proposed)

'Epigenetics in Evolution' (short video interview with Dr Eva Jablonka on epigenetics and Lamarck and implications for our current model of evolution).

Lamarck proposed a fully comprehensive theory of evolution, (and as noted also by Darwin, Lamarck did not invoke supernatural forces to explain his form of evolution. He relied instead on the natural laws and forces that drive the order of the cosmos as much as the higher organised matter of biological life as discussed above in relation to principles of form and growth. Lamarck also explored various modes of relatedness, such as hybridisation as also noted by Darwin. Genetic exchange at all levels of life, which as you will see further on, is actually turning out to be a significant contributor to evolutionary complexity.

And again, as noted by Darwin, Lamarck fully recognised the possibility of descent from other species, but not as simplistic as the literal model we employ today. An in-depth review of Lamarck's writings reveals a similar concept of distinct origins with differentiation from more generalist forms akin to Von Baer and D'Arcy Thompson's views on evolutionary development of the species. Like Von Baer, Lamarck understood that species were shaped and formed during development by their environments and interactions with fluids and substances – now described as epigenetic processes as revealed throughout a collection of excellent essays on Lamarck and his unrecognised contributions to evolutionary thought prior to his enforced dismissal by the Neo-Darwinists as seen in: TRANSFORMATIONS OF LAMARCKISM – from Subtle Fluids to Molecular Biology (2011) Link

Returning to the epigenetic type concept of the same genome, with different expressions of those genes at different times, as exemplified in the Epigenetic Caterpillar noted earlier, I have also dealt with the specific epigenetic effect of loss or gain of traits, features, even limbs and organs of species according to environmental triggers – a key concept within Lamarck's evolutionary theory, in Lamarck and the Sad Tale of the Blind Cave-Fish. As will be seen from a very important collection of epigenetic studies discussed below, essentially, genetic change (via mutations) is not actually the cause of blindness and even loss of eyes (physical cellular features that are not produced during developed as they are no longer required) in fish living in dark caves, it is seemingly epigenetic as the studies clearly indicate as seen below:

Chapter Fifteen taken from Epigenetic Principles of evolution

EVOLUTION BY LOSS

The neoDarwinian paradigm sees no other source of that information except mutations affecting the function of genes involved in the development of eyes in the fish, or the increase of the frequency of a preexisting allele (in such a case no new information would be necessary). But there is no evidence for relevant mutations to have occurred in genes related with eye development and there is no evidence that any allele for "eyelessness" existed in epigean forms of Astyanax. On the contrary, experimental evidence shows that all of these genes are functionally normal in both the blind cave fish and its conspecific eyed form. A number of investigators have argued against genetic mechanisms of the loss of eyes in cave fish: .....The fact that the evolutionary change leading to eyelessness in A. mexicanus implies no changes in genes unequivocally tells us that the evolutionary change is transmitted to the offspring by nongenetic means.

Cabej (2008-2012a)

Link

Evolution by Loss cont..,

What clearly have occurred in some experimentally determined cases of the loss of structures (loss of limbs in tetrapods, loss of eyes in A. mexicanus, loss of teeth in birds, etc.) are epigenetic changes in expression patterns of specific genes and gene regulatory networks.

Cabej (2008-2012a)

Link

EVOLUTION BY LOSS cont..,

As an inherited character, the evolutionary loss of eyes ... is not genetic, i.e. no changes in genes are involved ..., the remaining alternative is that the information for this radical change in morphology is epigenetic. ...

Cabej (2008-2012a)

Link

Now moving unto how Lamarck seen the fossil record and applied his theory to account for evolutionary adaptation. Recall that the epigenetic principle of evolution based on epigenetic developmental embryological observation by De Baer, is akin, as noted above, to Lamarck's views on the matter as seen in his most pertinent views on the matter. They are all taken from his 1809 'Zoological Philosophy...' (Translation by Hugh Elliot 1914)

... I shall show that nature, by giving existence in the course of long periods of time to all the animals and plants, has really formed a true scale in each of these kingdoms as regards the increasing complexity of organisation; but that the gradations in this scale, which we are bound to recognise when we deal with objects according to their natural affinities, are only perceptible in the main groups of the general series, and not in the species or even in the genera.

— Lamarck (1809, 58)

https://archive.org/stream/ZoologicalPhilosophy/ZoologicalPhilosophyAnimals_Lak_506pgs51391278#page/n129/mode/2up

The above quote reflects Von Baer's proposal of increasing scales and graduations of complexity within broad groups only. Lamarck seen species as adaptations from generalist forms, going from the less defined to the more specialised, but not necessarily from a single progressive origin. This generally reflects Von Baer and Thompson's concepts of generic forms being shaped by their experience and conditions of existence (environment) to form many variations of the same fundamental forms. Furthermore, in the broad reading of Lamarck's comprehensive theory, he continually refers to the dangers of over-classification of species and imposing our definitions too stringently. As it turns out, his warnings were well justified as it would seem that we have been too specific about species and their classification.

We have got distracted with all the detail and variation on the outside, the distracting details as pointed out by West for example and noted in the introduction. We tend to view the great variations that the fundamental themes display such as colours, the size and dimensions of birds' beaks or the arrangement of teeth and declare it a distinct species. Yet, epigenetics tells us that the colour, the size and the arrangement of teeth are adaptations to particular environments and conditions of existence (climate, resources, diet and interactions with other organisms), just as Lamarck proposed via deep and intensive study of actual specimens and his attention to the processes of Nature itself. Indeed, Lamarck viewed the fossil record, not so much as showing great extinctions, but of demonstrating the variation, the adaptation to different conditions and the so-called distinct species that seemed to appear after the demise of earlier fossils are actually the modified descendents of their ancestral (non-adapted) forms.

> *In the same climate, significantly different situations and exposures at first simply induce changes in the individuals who find themselves confronted with them. But as time passes, the continual difference in the situation of the individuals I'm talking about, who live and reproduce successively in the same circumstances, leads to changes in them which become, in some way, essential to their being, so that after many generations, following one after the other, these individuals, belonging originally to another species, find themselves at last transformed into a new species, distinct from the other.*
>
> *For example, if the seeds of a grass or of any other plant common to a humid prairie are transported, by some circumstance or other, at first to the slope of a neighbouring hill, where the soil, although at a higher altitude, is still sufficiently damp to allow the plant to continue living, if then, after living there and reproducing many times in that spot, the plant little by little reaches the almost arid soil of the mountain slope and succeeds in subsisting there and perpetuates itself through a sequence of generations, it will then be so changed that botanists who come across it there will create a special species for it.*
>
> *— Lamarck (1809, 39)*

https://archive.org/stream/ZoologicalPhilosophy/ZoologicalPhilosophyAnimals_Lak_506pgs51391278#page/n129/mode/2up

... among the fossil remains found of animals which existed in the past, there are a very large number belonging to animals of which no living and exactly similar analogue is known; and among these the majority belong to molluscs with shells, since it is only the shells of these animals which remain to us. Now, if a quantity of these fossil shells exhibit differences which prevent us, in accordance with prevailing opinion, from regarding them as the representatives of similar species that we know, does it not necessarily follow that these shells belong to species actually lost? Why, moreover, should they be lost, since man cannot have encompassed their destruction? May it not be possible on the other hand, that the fossils in question belonged to species still existing, but which have changed since that time and become converted into the similar species that we now actually find.

— Lamarck (1809, 45-46)

https://archive.org/stream/ZoologicalPhilosophy/ZoologicalPhilosophyAnimals_Lak_506pgs51391278#page/n129/mode/2up

Lamarck's ideas were essentially synonymous with epigenetics and his concepts were updated and investigated around the turn of 20th century within an age of genetics, at least until the suppression of all things Lamarckian by the philosophically-driven gene-centred form of Neo-Darwinism. Now, finally, the epigenetic scientific findings can no longer be ignored and studies such as those presented by Cabej above, clearly show how the Neo-Darwinian genetic mutation form of evolutionary change cannot explain real-time changes in species such as loss or gain of limbs, teeth, organs etc, but epigenetic studies can and show categorically that these changes are non-genetic (i.e., the genes don't change to effect these radical trait differences, but epigenetics – the change of gene expression can).

I will give you a few examples further on, after first reviewing just some of the major issues arising in more recent years with the fundamental assumptions embedded in the Neo-Darwinian model of evolution from direct genetic common ancestors. As you might imagine, our evolving and deeper understanding of the genome/epigenome leading to a scenario of descent with epigenetic/environmentally-driven formation of the species according to scaling/growth laws, will have profound implications for how we have historically viewed evolution.

'TRANSGENERATIONAL EPIGENETIC INHERITANCE: PREVALENCE, MECHANISMS, AND IMPLICATIONS FOR THE STUDY OF HEREDITY AND EVOLUTION'

The impact of epigenetics and epigenetic inheritance on evolutionary theory and the philosophy of biology will be profound.

Jablonka and Raz (2009) Theoretical and Practical Implications

Link

And as noted in the preface of the book entitled: 'Building the most Complex Structure on Earth: An Epigenetic Narrative of Development and Evolution of Animals' by Nelson R. Cabej:

I include in epigenetics the vast areas of the nongenetic mechanisms of reproduction, growth, cell differentiation, development, and evolution. It is in this broader context that epigenetics promises to be the genetics of the twenty-first century....

- Cabej (2013, preface).

This impact upon our current gene-centred model of evolutionary thinking is causing us to entirely rethink evolutionary processes in the light of not only non-genetic changes such as the epigenetic expression of genes, but in the light of genome remodeling – the changes that are quite rapid and profound which occur within the genes themselves (which is nothing to do with genetic mutations as described by our Modern Synthesis which I will touch on further on). But for now we will review just one of the evolutionary assumptions that our current conventional Neo-Darwinian model has run into.

For instance, there is an assumption that the more genetically similar a species: the more closely related it is on the evolutionary tree. Take for example, broccoli and cabbage. These are assumed to be more closely related based on their shared genes that code for proteins. We are told that as we share 75% of our genes with broccoli and a cabbage (of the 2% that code for proteins) according to our conventional wisdom, that this demonstrates our distance of relatedness on the branches of the Evolutionary (molecular) tree. These branches represent lineage splits from a common ancestor, and when these splits happened are supposed to be measurable using a molecular clock based upon genetic mutations.

The rate of DNA evolution: Effects of body size and temperature on the molecular clock

Observations that rates of molecular evolution vary widely within and among lineages have cast doubts on the existence of a single "molecular clock." Differences in the timing of evolutionary events estimated from genetic and fossil evidence have raised further questions about the accuracy of molecular clocks...

(Gillooly, Allen, West and Brown 2004, Abstract)

Link

You know, chimp/human split about 5/6 million years ago and out of Africa when Eve was our Mother and when, because of this clock ticking and her mitochondria DNA (which is only passed on along the female line). Then you might ask where does Adam come in? You find him some time later and then it gets really confusing as you probably imagine that Eve must have had virgin births and who begot EVE? The old chicken and egg problem arises. Well, it would appear that the molecular clock is running into some serious issues also as you will see below, with all its crazy fluctuations, it is leaving many more geneticists scratching their heads in puzzlement.

'DNA mutation clock proves tough to set'

Geneticists meet to work out why the rate of change in the genome is so hard to pin down.

In the past six years, more-direct measurements using 'next-generation' DNA sequencing have come up with quite different estimates. A number of studies have compared entire genomes of parents and their children — and calculated a mutation rate that consistently comes to about half that of the last-common-ancestor method.

A slower molecular clock worked well to harmonize genetic and archaeological estimates for dates of key events in human evolution, such as migrations out of Africa and around the rest of the world1. But calculations using the slow clock gave nonsensical results when extended further back in time — positing, for example, that the most recent common ancestor of apes and monkeys could have encountered dinosaurs. Reluctant to abandon the older numbers completely, many researchers have started hedging their bets in papers, presenting multiple dates for evolutionary events depending on whether mutation is assumed to be fast, slow or somewhere in between.

—Callaway (2015, in Nature 10th March)

Link

As we are beginning to realise it is increasingly difficult to show that the genetic similarity of different species can be accurately plotted and pinned onto the molecular tree according to the Neo-Darwinian assumption that evolution happened via genetic mutations – that could only be handed down directly –

NO LAMARCKY MALARKY

But, as genetic mutations don't actually account for adaptations~

'EVOLUTION OF DRUG-RESISTANT BACTERIA'

Bacteria in nature do evolve resistance to antibiotics faster than mutation and selection allow... "

— Campbell and Schopf (1994, 95)

Link

Imagine if evolution had happened according to Lamarckian and other non-Darwinian principles... You would be able to explain the seemingly miraculous transformation from a sluggy-type creature into an elegant flying insect. Environmentally-driven adaptive evolution via epigenetic modification without changing the code itself (how genes are expressed differently) is enough to make us re-evaluate the entire way life may have become so complex and diverse. Below are a few epigenetic studies that demonstrate quite radical and rapid changes in real-time and present day species that are not related to the change of the genes themselves, just its expression. Epigenetics works like chemical switches and can turn genes on or off or regulate expression much like a dimmer switch as well as effect changes to genes (expression) according to how tightly or loosely your chromosomes are packaged in your cells.

If we consider something like the epigenetic caterpillar analogy (i.e. a caterpillar and its adult form ~ a moth or butterfly), now, if we didn't know any better and we found these two organisms in the fossil record (slug-like creatures near the bottom) and nothing environmentally changes and then, suddenly everything changes and we see just above this level a fully-formed flying insect (albeit a little spindly and primitive looking – we actually see this in the fossil record if you look closely and apply Von Baer's laws), might you not perceive these creatures as entirely distinct from one another? Anyway, that is just a thought experiment for now and I will present the supporting evidence to go along with it. But, it is interesting don't you think?

Epigenetics can also explain the loss of limbs as in lizards becoming snakes, eggs coding for male or female depending upon the temperature as you will see below. Below are some recent epigenetic studies that demonstrate large and rapid changes within existing species that are affected without changing the genes themselves, just how they are expressed epigenetically. Note that these experiment do not change one species into another, just their traits and the reason for this is presumably due to the fact that all life on earth has reached that metabolic equilibrium in tune with its environmental niche and therefore has become stabilised as a species – or as Von Baer predicted, they have reached their species maturity (adult) form. However, the epigenetic changes can still be profound and can activate or reactivate earlier ancestral features as you will see further on.

Honey, I shrunk the ants: How environment controls size

By increasing the degree of DNA methylation (a biochemical process that controls the expression of certain genes -- a bit like a dimmer can turn a light up or down) of a gene involved in controlling growth ... they were able to create a spectrum of worker ant sizes despite the lack of genetic difference between one ant and the next. Essentially, the researchers found that the more methylated the gene, the larger the size of the ants...

"We were working with ants, but it was a bit like discovering that we could create shorter or taller human beings."

(source: Mc Gill University, March 11, 2015)

http://www.sciencedaily.com/releases/2015/03/150311081258.htm

Molecular mechanism links temperature with sex determination in some fish species

A study led by the CSIC's Institute of Marine Sciences, in collaboration with researchers from the Centre for Genomic Regulation (CRG), has found the epigenetic mechanism that links temperature and gonadal sex in fish. High temperature increases DNA methylation of the gonadal aromatase promoter in female.

The environmental temperature has effects on sex determination. There are species, such as the Atlantic silverside fish, whose sex determination depends mainly on temperature. And there are other species whose sex determination is written within its DNA but still temperature can override this genetic 'instruction'.

Centre for Genomic Regulation, (Jan 2nd 2012)

Link

Well if epigenetic methalation has the ability to override chromosomes or their equivalent that make you male or female and temperature is the driving force, what else did epigenetic and environmentally-driven factors do to change the traits and characters of an evolving species? The mind boggles at the possibilities. Hopefully you are beginning to see Nature's powerful ability to adapt her species to whatever the weather; and cut her clothe to her measure. Adaptation depending upon which way the wind is blowing, especially when the species is developing in evolutionary time-scales.

Now can you see how a big fish in a small pond may not do very well, but if its eggs spawn a new generation of fish, nature just might shrink them so that they not only survive, but thrive in that same pond as it can do it really quickly. Nature has developed a fairly ingenious way of operating whole swathes of genes during development that works a bit like a master switch.

For instance, as reported in Science Daily, with the heading: 'Millions of DNA switches that power human genome's operating system are discovered' (2012) sourced from the University of Washington, the summary explains the role and discovery of these Hox Gene complexes and how they were, until recently, hidden within the genome (within the so-called junk regions again) in the following:

Genes make up only 2 percent of the human genome and are easy to spot, but the on/off switches controlling those genes were encrypted within the remaining 98 percent of the genome. Without these switches, called regulatory DNA, genes are inert ...

http://www.sciencedaily.com/releases/2012/09/120905135326.htm

So it isn't just a case of your genes being unpacked and read and the proteins built according to a fixed set of instructions, but rather a fairly flexible set of instructions that are open to interpretation (epigenetic memory) according to environmental cues. These Hox master gene switches and epigenetic factors are specifically noted in the article relating to the NOVA channel: 'Ghosts in your genes' just below and I have referenced a few other articles that clearly show the importance of the role of epigenetics in how, what, when and to what degree these genetic master switches are deployed:

...Gene switches such as Ubx make the initial decisions of which genes to turn on or off in different body regions and cell types... This highly evolved, highly orchestrated ability to make genes active or inactive—both genetically and epigenetically—is the key to the success of multicellular plants and animals, including the most complex and mysterious of all, us.

http://www.pbs.org/wgbh/nova/genes/fate-nf.html

And the epigenetic aspect of Hox-gene activation and its rapidity and importance during development is highlighted in the few article excerpts such as: in the journal of Science (2009) entitled: Epigenetic temporal control of mouse Hox genes in vivo http://www.ncbi.nlm.nih.gov/pubmed/19498168 is one of many linking the Hox gene complexes to epigenetic control and others include:

Epigenetic mechanism for fast-tracking evolution

The outcome is profoundly influenced by the role of epigenetics through transcriptional regulation of key developmental genes. Epigenetics refer to changes in gene expression that are inherited through mechanisms other than the underlying DNA sequence, which control cellular morphology and identity. It is currently well accepted that epigenetics play central roles in regulating mammalian development and cellular differentiation by dictating cell fate decisions via regulation of specific genes.

Among these genes are the Hox family members, which are master regulators of embryonic development and stem cell differentiation ... Hox gene expression during development is tightly regulated in a spatiotemporal manner, partly by chromatin structure and epigenetic modifications. Here, we review the impact of different epigenetic mechanisms in development and stem cell differentiation with a clear focus on the regulation of Hox genes.

Ann Anat. 2010 Sep 20;192(5):261-74. doi: 10.1016/j.aanat.2010.07.009. Epub 2010 Aug 6. http://www.ncbi.nlm.nih.gov/pubmed/20739155

Epigenetic regulation of vertebrate Hox genes: a dynamic equilibrium.

Temporal and spatial control of Hox gene expression is essential for correct patterning of many animals.

Epigenetics. 2009 Nov 16;4(8):537-40. Epub 2009 Nov 21

http://www.ncbi.nlm.nih.gov/pubmed/19923920

Another science paper entitled: Epigenetic control of Hox genes during neurogenesis, development, and disease (2010) http://www.ncbi.nlm.nih.gov/pubmed/20739155 outlines some of these epigenetic mechanisms and their role in the activation of Hox genes. Another paper which outlines the following:

the process of mammalian development is established through multiple complex molecular pathways acting in harmony at the genomic, proteomic, and epigenomic levels. The outcome is profoundly influenced by the role of epigenetics through transcriptional regulation of key developmental genes. Epigenetics refer to changes in gene expression that are inherited through mechanisms other than the underlying DNA sequence, which control cellular morphology and identity. It is currently well accepted that epigenetics play central roles in regulating mammalian development and cellular differentiation by dictating cell fate decisions via regulation of specific genes.

Among these genes are the Hox family members, which are master regulators of embryonic development and stem cell differentiation ... Hox gene expression during development is tightly regulated in a spatiotemporal manner, partly by chromatin structure and epigenetic modifications.

Ann Anat. 2010 Sep 20;192(5):261-74. doi: 10.1016/j.aanat.2010.07.009. Epub 2010 Aug 6. http://www.ncbi.nlm.nih.gov/pubmed/20739155

The epigenetic differential expression of genes and particularly early on as they are being activated or not activated/expressed or not-expressed, when and to what degree, can have a big impact on what an organism ends up looking like in the end and indeed can shape its entire evolutionary trajectory.

For instance, in a paper by Gilbert S. F. in Developmental Biology (2000) entitled: Hox Genes: Descent with Modification as the title implies, Gilbert views evolution as being driven in part by a commonly shared process/mechanism, a tool-kit, if you like, by which basic body-plans of organisms such as animals can be laid out (built) according to a specific set of instructions as Gilbert states: "This means that the enormous variation of morphological form in the animal kingdom is underlain by a common set of instructions" Link.

Well, perhaps, but these instructions are open to epigenetic interpretation. These instructions are not fixed – it just saves Nature a great deal of time in doing the initial body printout, not having to reinvent the wheel every time. The summary of Cabej's book, 'Building the most complex structures on Earth' describes the epigenetic role in this genetic toolkit as follows:

This is a novel theory that describes the epigenetic mechanisms of the development and evolution of animals and explains the colossal evolution and diversification of animals from a new post-genetic perspective. Modern biology has demonstrated the existence of a common genetic toolkit in the animal kingdom, but neither the number of genes nor the evolution of new genes is responsible for the development and evolution of animals. The failure to understand how the same genetic toolkit is used to produce millions of widely different animal forms remains a perplexing conundrum in modern biology. The novel theory shows that the development and evolution of the animal kingdom are functions of epigenetic mechanisms, which are the competent users of the genetic toolkit.

http://store.elsevier.com/Building-the-Most-Complex-Structure-on-Earth/Nelson-Cabej/isbn-9780124016675/

The hox complexes are genetic switches and are essential for the activation of the initial body patterns during development. These are ultimately controlled and guided via epigenetic processes operating above the genes themselves, and act as controllers of the master genetic switches.

Gilbert gives a very solid example of just what these Hox complexes can end up expressing or not, in the following interesting example of the evolutionary history of how the snake lost its legs:

One of the most radical alterations of the vertebrate body plan is seen in the snakes. Snakes evolved from lizards, and they appear to have lost their legs in a two-step process. Both paleontological and embryological evidence supports the view that snakes first lost their forelimbs and later lost their hindlimbs ... Fossil snakes with hindlimbs, but no forelimbs, have been found. Moreover, while the most derived snakes (such as vipers) are completely limbless, more primitive snakes (such as boas and pythons) have pelvic girdles and rudimentary femurs. The missing forelimbs *can be explained by the Hox expression pattern in the anterior portion of the snake. In most vertebrates, the forelimb forms just anterior to the most anterior expression domain of Hoxc-6 ...*

http://www.ncbi.nlm.nih.gov/books/NBK9978/

Epigenetics processes acting upon the genomes of various organisms, not only begins to account for the dramatic and rapid formation of fundamental 'principal types', epigenetic evolution also appears to be responsible for the great variation of forms of these fundamental themes, as it acts via differential genetic expression of these fundamental forms throughout the life span of a species, albeit in a less dramatic way as the species become more mature and reach their adult form. The continuation and fine-tuning (at a micro-evolutionary level of development) of all this epigenetic variation in gene expression is clearly seen as ongoing, as exemplified within to-day's species.

In other words, genes don't run the evolutionary show, although they provide the raw genetic material for other processes to operate upon. It how these genes are expressed epigenetically that makes sense of all this genetic novelty. It is how nature uses the genetic code and produces 'intelligent designs' that would seem, according to the evidence that produces specialist species that are perfectly adapted to their environmental niches.

Now are you beginning to see how switches according to environmental needs and adaptations while an organism was developing as a species, if we literally apply Von Baer's laws, the earlier and more primitive forms have shorter evolutionary gestation periods and the later and more complex forms have longer evolutionary gestation periods – all start out as generalists and via epigenetic environmental changes, become more defined and more diverse from each other.

And don't forget of course, all the genetic novelty that some organisms had to play within their tool-kit for adaptations and how ultimate evolutionary trajectory of the species was directed by their inherent molecular complexity according to scaling laws of growth/development and efficiency to being all it could be from all that it had picked up and experienced in its environment on its evolutionary journey. This brings us to the many ways that organisms incorporated new and novel genetics into their genomes and how these genes themselves can be edited and moved around.

CHAPTER FIVE

JUMPING GENETICS

Fig. 18: Photo of Barbara McClintock taken at Caltech [Public Domain via Wikimedia Common]

Barbara McClintock

The discovery of jumping genes

Jumping genes can go between species (HGT – horizontal gene transfer which I will discuss further on) creating genetic novelty and can jump around within genomes. Barbara Mc Clintock discovered genes that jump around genomes and made some pretty profound changes along the way. Now if we consider epigenetic factors have shaped and molded species according to their needs, inherent metabolic complexity within evolutionary timescales. And we consider that these factors operate above the genes and changes their expression via environmental conditions and is implicated in remodeling species via epigenetic differences of genetic expression (recall the same genome in identical twins and or, a caterpillar and flying insect with the same genome but differently expressed epigenome), well you might begin to imagine how mobile elements or transposable elements, also known as jumping genes, can remodel existing genes and when this is combined with epigenetics (the expression of those genes according to experience which can be inherited), then we are beginning to see a very dynamic means of changing species in the evolutionary past.

Furthermore, when we bring scaling laws and growth laws into the equation (relating to metabolic development in tune with resources and the conditions of existence – the environment), we can see that species development is a highly orchestrated natural process, not a randomly-driven one as our current model of evolution proposes. Returning now to McClintock's discovery, the following biography reveals the historical context of her discovery: by Sandeep Ravindran, Science Writer.

Muted Reaction

For much of the 20th century, genes were considered to be stable entities arranged in an orderly linear pattern on chromosomes, like beads on a string (1). In the late 1940s, Barbara McClintock challenged existing concepts of what genes were capable of when she discovered that some genes could be mobile...

By the 1970s the great strides made in molecular biology led to the discovery of transposons in other organisms, starting with viruses and bacteria. We now know that transposons constitute more than 65% of our genomes and approximately 85% of the maize genome....

Confirmation that transposons were widespread among eukaryotes eventually led to the wider appreciation of her original discovery. McClintock received a number of prestigious awards, including the 1970 National Medal of Science and culminating in an unshared Nobel Prize in Physiology or Medicine in 1983...McClintock described the initial reaction to her discovery as "puzzlement, even hostility"... Speaking of the scientific community at large she said "I was startled when I found they didn't understand it; didn't take it seriously"... The concept of transposition did not fit easily within the framework of genetics at the time... These pioneering studies foreshadowed later work showing the importance of epigenetics, heritable changes not caused by changes to the DNA sequence, in development.

http://www.pnas.org/content/109/50/20198.full

http://www.nobelprize.org/mediaplayer/index.php?id=1617

In her paper presented during her Nobel award in 1983, entitled: THE SIGNIFICANCE OF RESPONSES OF THE GENOME TO CHALLENGE she writes:

It is the purpose of this discussion to consider some observations from my early studies that revealed programmed responses to threats that are initiated within the genome itself, as well as others similarly initiated, that lead to new and irreversible genomic modifications. These latter responses, now known to occur in many organisms, are significant for appreciating how a genome may reorganize itself when faced with a difficulty for which it is unprepared. Conditions known to provoke such responses are many. A few of these will be considered, along with several examples from nature implying that rapid reorganizations of genomes may underlie some species formations.

...

In the future attention undoubtedly will be centered on the genome, and with greater appreciation of its significance as a highly sensitive organ of the cell, monitoring genomic activities and correcting common errors, sensing the unusual and unexpected events, and responding to them, often by restructuring the genome.

http://www.nobelprize.org/nobel_prizes/medicine/laureates/1983/mcclintock-lecture.pdf

James A Shapiro refers to nature's molecular mechanism for rearranging genomes or, the role of jumping genes as established by McClintock, as natural genetic engineering (NGE) as an alternative and much more dynamic and explanatory process for how species may have evolved. In other words, Shapiro proposes that it is neither slow or gradual and therefore quite contrary to the more traditional view of genetic based population models with their accidental mutations being naturally selected, environmentally, giving a creature adaptive traits and therefore a better chance of survival. NGE is a dynamic, rapid response system that reprograms genes via responsive cellular mechanisms according to environmental challenges.

These mobile (genetic) elements that move around the genome, cut, paste, delete and re-arrange existing DNA are sometimes called Jumping genes and are also referred to as transposons creating insertions and deletions within the genome. James Shapiro's research in our present time has always acknowledged McClintock's discoveries as highly significant. Below Shapiro discusses the type of flexibility of the genome alluded to by Barbara McClintock:

Natural genetic engineering in evolution J.A. Shapiro

In other words, it can be argued that much of genome change in evolution results from a genetic engineering process utilizing the biochemical systems for mobilizing and reorganizing DNA structures present in living cells.

Genetica 86: 99-111, 1992.

http://shapiro.bsd.uchicago.edu/Shapiro.1992.Gentica.NatGenEngInEvo.pdf

Bearing this natural genetic engineering process in mind, the following study is of some interest and might give us an insight into this natural genetic engineering in action. One fairly drastic way of re-modelling genomes (ala: Prof. James A. Shapiro's natural genetic engineering as discussed above), is to relax the epigenetic control of gene expression and trigger mobile genetic elements (TEs) or jumping genes into action. For instance, regarding epigenetics and jumping genes as an evolutionary mechanism in the science journal Gene, by Rita Rebolloa et al (2010) state the following in their article entitled: 'Jumping genes and epigenetics: Towards new species':

Transposable elements (TEs) are responsible for rapid genome remodeling by the creation of new regulatory gene networks and chromosome restructuring. TEs are often regulated by the host through epigenetic systems, but environmental changes can lead to physiological and, therefore, epigenetic stress, which disrupt the tight control of TEs. The resulting TE mobilization drives genome restructuring that may sometimes provide the host with an innovative genetic escape route. We suggest that macroevolution and speciation might therefore originate when the host relaxes its epigenetic control of TEs.

http://www.sciencedirect.com/science/article/pii/S0378111910000296

In other words as much as epigenetics is the guiding force to adapt the species, sometimes those jumping genes come to the rescue when something more radical is called for and when they do, it is like a rapid response system, an SOS type of mechanism that Nature has developed within each and every organism. How else do you think bacteria adapt so rapidly to a new antibiotic?

Essentially, Nature has not created slavishly-driven robotic gene carriers as postulated by Richard Dawkins and others, but instead it is all about adaptability and this of course has significance for how evolutionary development of the species occurred in response to environmental upheavals and dramatic changes. It is important to also bear in mind that as the species (like an embryo) is highly susceptible to change prior to becoming more fixed as a species (akin to Von-Baer's adult species forms), that mobile elements in conjunction with epigenetic factors, ultimately driven by natural forces of shape and form according to available resources, must have impacted significantly upon early species development.

Jumping genes are proving in more recent times to be evolutionary significant across the board and found to have impacted greatly even on our own evolutionary development. This flexibility of the organism's geneome and its ability to be remodeled (reprogrammed) according to adaptive needs and seemingly triggered by environmental cues, reveals a distinctly different evolutionary scenario to the fixed and predetermined form proposed by our standard evolutionary model. Again Shapiro summarises this as follows:

~ James A. Shapiro ~

HOW LIFE CHANGES ITSELF: THE READ-WRITE (RW) GENOME

The genome has traditionally been treated as a Read-Only Memory (ROM) subject to change by copying errors and accidents. In this review, I propose that we need to change that perspective and understand the genome as an intricately formatted Read–Write (RW) data storage system constantly subject to cellular modifications and inscriptions.

Cells operate under changing conditions and are continually modifying themselves by genome inscriptions. These inscriptions occur over three distinct time-scales (cell reproduction, multicellular development and evolutionary change) and involve a variety of different processes at each time scale

(forming nucleoprotein complexes, epigenetic formatting and changes in DNA sequence structure)

... This conceptual change to active cell inscriptions controlling RW genome

functions has profound implications for all areas of the life sciences.

— Shapiro (2013) Abstract

For instance, in another science journal (2002) entitled: 'Transposable Elements and Eukaryotic Complexity' by Nathan J. Bowen and I. King Jordan outline the importance of TEs (Jumping genes) make up a very large part of our genome and appear to have played a major role in evolution (complex cellular life making up plants and animals are Eukaryotes)

Eukaryotic transposable elements are ubiquitous and widespread mobile genetic entities. These elements often make up a substantial fraction of the host genomes in which they reside. For example, approximately 1/2 of the human genome was recently shown to consist of transposable element sequences. There is a growing body of evidence that demonstrates that transposable elements have been major players in genome evolution. A sample of this evidence is reviewed here with an emphasis is on the role that transposable elements may have played in driving the evolution of eukaryotic complexity. A number of specific scenarios are presented that implicate transposable elements in the evolution of the complex molecular and cellular machinery that are characteristic of the eukaryotic domain of life.

http://www.horizonpress.com/cimb/v/v4/07.pdf

~Oliver & Green ~

'JUMPING GENES DRIVE EVOLUTION'

Orthodox evolutionary theory does not tally with the fossil record, but a new school of thought points towards 'jumping genes' as essential agents of periodic changes in the rate of evolution … Punctuated equilibrium is rapid evolution followed by slow evolution, or a stoppage in evolution, as is observed in the fossil record.

This can be explained by the fact that jumping gene activity does not occur at a low and uniform rate over time. Instead, it sporadically occurs in sudden bursts resulting in rapid evolution, followed by decreasing activity and slowing evolution. These rapid bursts of evolution can happen when a new type of jumping gene is suddenly transferred into a lineage from some other lineage, or when a new type of jumping gene naturally emerges from within a genome.

— Oliver & Greene (2009) 'Australasian Science' September Edition

http://researchrepository.murdoch.edu.au/6496/1/jumping_genes.pdf

-Oliver & Green -

'How Jumping Genes Drove Primate Evolution'

Jumping genes have been important in the evolution of higher primates, leading to faster brain function, improved foetal nourishment, useful red-green colour discrimination and greater resistance to disease-causing microbes – and even the loss of fat storage genes in gibbons.

http://www.australasianscience.com.au/article/issue-january-and-february-2012/how-jumping-genes-drove-primate-evolution.html

— Oliver & Greene (2012) 'Australasian Science'

Jan / Feb Edition

http://www.australasianscience.com.au/article/issue-january-and-february-2012/how-jumping-genes-drove-primate-evolution.html

Here is an example of how important transposable elements are seen in terms of larger evolutionary adaptations and how jumping genes are not confined to the world of plants, as one science paper by John McDonald, professor in the department of genetics at the University of Georgia, in a science paper entitled: Transposable Elements May Have Had A Major Role In The Evolution Of Higher Organisms (1998) shows:

It now appears that at least some transposable elements may be essential to the organisms in which they reside. Even more interesting is the growing likelihood that transposable elements have played an essential role in the evolution of higher organisms, including humans.

http://www.eurekalert.org/pub_releases/1998-02/UoG-TEMH-090298.php

CHAPTER SIX

THE WEB-LIKE TREE OF LIFE

Fig. 19: Photo of Carl Woese [Public Domain via Wikimedia Common]

Carl Woese

(1928 –2012)

American microbiologist and biophysicist.

The Man who rewrote the tree of life

Carl Woese may be the greatest scientist you've never heard of. "Woese is to biology what Einstein is to physics," says Norman Pace, a microbiologist at the University of Colorado, Boulder. A physicist-turned-microbiologist, Woese specialized in the fundamental molecules of life—nucleic acids—but his ambitions were hardly microscopic. He wanted to create a family tree of all life on Earth.

Carey 2014

http://www.pbs.org/wgbh/nova/next/evolution/carl-woese/

Woese is famous for defining a new domain of life known as Archaea. In the 1970s, he pioneered a technique that revolutionised the field of microbiology. But most importantly, he redefined the tree of life as a web showing that genetically, domains of microbial life was teeming with little hybrids. Or what has been referred to as genetic material transferred across all domains of fungi, bacteria etc known as HGT (horizontal gene transfer).

Essentially, what Woese discovered was that early life was a web full of horizontal gene transfer (HGT) which is a direct way of more primitive life-forms exchanging genetics akin to hybridation between distinct species, but a more direct way of exchanging genetics across whole domains of life and diverse species types. Jumping genes have been referred to as a type of HGT within species, but Woese's research was within the tiny world of microbes where HGT was seemingly a common occurrence.

As you will see below, HGT goes on and has been part of the evolution of the larger world of plants and animals and ourselves. HGT is essentially a very fast-track way of making a rather radical genetic change and we can see its evidence as it has left its footprints all over the genomes of even the more complex animals.

The exchange of genetics via horizontal gene transfer, reflects a more direct and rapid form of genetic exchange that most of us are more familiar with – hybridization. This latter form, is as most of know, particularly regarding plants, is a fast-track means of creating a new and novel form of variation and even distinct species even today. As you will see further on, hybridization was actually much more common in the evolutionary past and crossed many species boundaries that we believed to be impassable. This form of novel gene exchange is known as vertical gene transfer, whereas, horizontal gene transfer is much more direct and was seemingly rampant between vastly different species as the following articles reveals. It is now known to be an important aspect of eukaryote (animals and plants of multicellular life) as well.

'HORIZONTAL GENE ACQUISITIONS BY EUKARYOTES AS DRIVERS OF ADAPTIVE EVOLUTION'

In contrast to vertical gene transfer from parent to offspring, horizontal (or lateral) gene transfer moves genetic information between different species. Bacteria and archaea often adapt through horizontal gene transfer. Recent analyses indicate that eukaryotic genomes, too, have acquired numerous genes via horizontal transfer from prokaryotes and other lineages. Based on this we raise the hypothesis that horizontally acquired genes may have contributed more to adaptive evolution of eukaryotes than previously assumed. Current candidate sets of horizontally acquired eukaryotic genes may just be the tip of an iceberg.

— Schönknecht et al (2013) Abstract

http://onlinelibrary.wiley.com/doi/10.1002/bies.201300095/abstract;jsessionid=2B28066CC31570B158F2D72C1550CE91.f01t03

'COWS ARE 25 PERCENT SNAKE'

You vaguely know how DNA works, right? You get it from your parents. Well, hold onto your britches, because scientists from down under are about to turn your world upside down. A study by Australia's Adelaide and Flinders Universities and the South Australian Museum has found that in complex organisms, DNA is not only transferred from a parent to its offspring like your science book told you, but can also be "laterally" transferred between species. The research, published in the peer-reviewed Proceedings of the National Academy of Sciences in the US, involved comparing dozens of DNA sequences from different species. It found that cows inherited up to a quarter their genes from reptiles ...

— Eichelberger (2013) 'Mother Jones.com', 3rd January Edition

http://www.motherjones.com/blue-marble/2013/01/dna-cows-snakes-adelaide-flinders-study

Space Invader DNA jumped across mammalian genomes

Genomes are often described as recipe books for living things. If that's the case, many of them badly need an editor. For example, around half of the human genome is made up of bits of DNA that have copied themselves and jumped around, creating vast tracts of repetitive sequences. The same is true for the cow genome, where one particular piece of DNA, known as BovB, has run amok. It's there in its thousands. Around a quarter of a cow's DNA is made of BovB sequences or their descendants.

BovB isn't restricted to cows. If you look for it in other animals, as Ali Morton Walsh from the University of Adelaide did, you'll find it in elephants, horses, and platypuses. It lurks among the DNA of skinks and geckos, pythons and seasnakes. It's there in purple sea urchin, the silkworm and the zebrafish.

The obvious interpretation is that BovB was present in the ancestor of all of these animals, and stayed in their genomes as they diversified. If that's the case, then closely related species should have more similar versions of BovB. The cow version should be very similar to that in sheep, slightly less similar to those in elephants and platypuses, and much less similar to those in snakes and lizards.

But not so. If you draw BovB's family tree, it looks like you've entered a bizarre parallel universe where cows are more closely related to snakes than to elephants, and where one gecko is more closely related to horses than to other lizards.

This is because BovB isn't neatly passed down from parent to offspring, as most pieces of animal DNA are. This jumping gene not only hops around genomes, but between them.

This type of "horizontal gene transfer" (HGT) is an everyday event for bacteria, which can quickly pick up important abilities from each other by swapping DNA. Such trades are supposedly much rarer among more complex living things, but every passing year brings new examples of HGT among animals. For example, in 2008, Cedric Feschotte (now at the University of Utah) discovered a group of sequences that have jumped between several mammals, an anole lizard, and a frog. He called them Space Invaders.

(Yong - In Phenomena: 'National Geographic' November 3, 2008)

http://phenomena.nationalgeographic.com/2008/11/03/space-invader-dna-jumped-across-mammalian-genomes/

'The Human Genome Race

A tale of the Tortoise and the Hare... and the fly and the worm and the mouse'

Soon after the Human Genome Project published its preliminary results in 2001, a group of scientists announced that a handful of human genes—the consensus today is around 40—appear to be bacterial in origin. The question that remains, however, is how exactly they got there. Some scientists argue that the genes must have been transferred to humans from bacteria fairly recently in evolutionary history, because the genes aren't found in our closest animal ancestors.

— Karow (2000) 'Scientific America' April 24th Edition

http://www.scientificamerican.com/article/the-human-genome-race/

So you try deciphering where we come in the family tree and how related to snakes are we really? This great web of life, seemingly extends all the way down to the roots of the so-called family tree. Now if you take adaptive and environmentally-driven epigenetics (remodeling of species via genetic expression), jumping genes (rapid adaptive remodeling of existing genomes) and novel genetic exchange into the equation, we are beginning to see a means of species change and adaptation that doesn't require genetic mutations of slow and gradual and random-type evolution proposed by the Neo-Darwinists. Indeed, as you are hopefully starting to see and will see more evidence further on, this later form of evolutionary change via genetic mutations doesn't actually account for change in real terms; whereas, epigenetics and jumping genetics does.

Also, as highlighted earlir, the whole genetic mutation assumption upon which we build our molecular trees and use to determine relatedness in genetic terms (the closer the genetic similarity: the closer the evolutionary relatedness), doesn't work in real terms either. Woese and others have assessed the earlier tree of life concept and tested it and found that essentially it is a misnomer. It is a bush, a web and may involve many origins and divergences.

~ Carl Woese ~

'THE UNIVERSAL ANCESTOR'

The universal ancestor is not an entity, not a thing.

It is a process characteristic of a particular evolutionary stage.

— Woese (1998) Conclusion

'A FUNDAMENTALLY NEW PERSPECTIVE ON THE ORIGIN AND EVOLUTION'

Darwin's hypothesis that all extant life forms are descendants of a last common ancestor cell and diversification of life forms results from gradual mutation plus natural selection represents a mainstream view that has influenced biology and even society for over a century. However, this Darwinian view on life is contradicted by many observations and lacks a plausible physico-chemical explanation. Strong evidence suggests that the common ancestor cell hypothesis is the most fundamental flaw of Darwinism…

— Liu (2008) Abstract

'PATTERN PLURALISM AND THE TREE OF LIFE HYPOTHESIS'

Darwin claimed that a unique inclusively hierarchical pattern of relationships between all organisms based on their similarities and differences [the Tree of Life (TOL)] was a fact of nature, for which evolution, and in particular a branching process of descent with modification, was the explanation. However, there is no independent evidence that the natural order is an inclusive hierarchy, and incorporation of prokaryotes into the TOL is especially problematic...

— Doolittle and Bapteste (2007) Abstract

'THE CONCEPT OF MONOPHYLY: A SPECULATIVE ESSAY'

Recent research results make it seem improbable that there could have been single basal forms for many of the highest categories of evolutionary differentiation (kingdoms, phyla, classes). The universal tree of life probably had many roots.

— Gordon (1999, 331) Abstract

CHAPTER SEVEN

EVOLUTION BY MERGERS (WHOLE GENEOME EXCHANGE): NOT VIA MUTATIONS

Fig. 20: Photo of Lynn Margulis [Public Domain via Wikimedia Common]

Lynn Margulis

Whole Organism Mergers & Mating Rituals in the Microbial World

In Margulis' article, entitled: The Phylogenetic Tree Topples (2006) and an another publication: Acquiring Genomes: A Theory of the Origins of the Species, microbial life is described as having evolved by fairly opportunistic and unusual methods, such as: genome stealing, symbiosis and entire microbial worlds merging to become whole new kingdoms/classes of life may begin to explain the distinct origins and rather web-like pattern of the earlier evolutionary record as described above. The following interview article explains Margulis' theory of how complex life may have come about via mergers of microbial life:

Evolutionist Lynn Margulis showed that a major organizational event in the history of life probably involved the merging of two or more lineages through symbiosis.

Symbiotic microbes = eukaryote cells?

In the late 1960s Margulis studied the structure of cells. Mitochondria, for example, are wriggly bodies that generate the energy required for metabolism. To Margulis, they looked remarkably like bacteria. She knew that scientists had been struck by the similarity ever since the discovery of mitochondria at the end of the 1800s. Some even suggested that mitochondria began from bacteria that lived in a permanent symbiosis within the cells of animals and plants. There were parallel examples in all plant cells. Algae and plant cells have a second set of bodies that they use to carry out photosynthesis. Known as chloroplasts, they capture incoming sunlight energy. The energy drives biochemical reactions including the combination of water and carbon dioxide to make organic matter. Chloroplasts, like mitochondria, bear a striking resemblance to bacteria. Scientists became convinced that chloroplasts ...like mitochondria, evolved from symbiotic bacteria — specifically, that they descended from cyanobacteria ... the light-harnessing small organisms that abound in oceans and fresh water.

When one of her professors saw DNA inside chloroplasts, Margulis was not surprised. After all, that's just what you'd expect from a symbiotic partner. Margulis spent much of the rest of the 1960s honing her argument that symbiosis ... was an unrecognized but major force in the evolution of cells. In 1970 she published her argument in The Origin of Eukaryotic Cells.
http://evolution.berkeley.edu/evolibrary/article/history_24

We can infer that bacteria from the research of Margulis for instance, that some bacteria adapted after mergers with certain cellular life and formed a whole domain of scaled up complexity known as eukaryotes – that's you and me as well as all the plants and animals. We can propose that other forms of bacteria remained as bacteria once they became stabilised and began specialising as free-living bacteria that we know exist today. There were other bacterial life-forms that are symbiotic (as in the bacteria that keeps us alive and lives in our guts), they apparently co-evolved with other species and got pretty smart by hitching a ride within other complex organisms. So in a sense, although they are still bacteria, (and they are not all bad), they have continued to evolve and adapt according to many different conditions and environments and modes of existence.

For instance, the mergers of simple organisms to form much more complex ones like the eukaryotes (ourselves, including other multi-cellular organisms - animals and plants), as proposed by Margulis could be viewed as a type of evolutionary replay of how more primitive organisms evolved if we observe present day organisms such as yeast and bacteria who use fission/fusion, not unlike how sperm with tails enter eggs for example in the initial stages of forming a more complex organism such as ourselves. Margulis suggests that this was the origin of the fertilisation of the egg by symbiotic sperms, but seemingly in the early days of evolutionary development (and used as a mode of reproduction today by many simpler. Yes, the thought of yeast and bacteria acting out a primitive sex act under the right environmental conditions (perhaps an ambient mood and lighting) by giving off signals to attract mates do not fully merge, but transfer their genetics via a little tail. Rather dramatic don't you think? See article excerpt below for what mating yeast get up to.

Mate and fuse: how yeast cells do it.

Many cells are able to orient themselves in a non-uniform environment by responding to localized cues. This leads to a polarized cellular response, where the cell can either grow or move towards the cue source. Fungal haploid cells secrete pheromones to signal mating, and respond by growing a mating projection towards a potential mate. Upon contact of the two partner cells, these fuse to form a diploid zygote.

-(Merlini et al Abstract)

http://www.ncbi.nlm.nih.gov/pubmed/23466674

Sponge animals and jelly fish are relatively simple animals compared to other animal forms such as invertebrate (animals with exo-skeleton on the outside) of which group the insects are the most complex, or the vertebrate animals (with a back bone and interior skeleton) and remain as such to-day. However, some soft-bodied animals went on to become mollusks and grow protective shells of every shape, size, colour and hue and patterning, but still remain as mollusks. Obviously, embryonic soft-bodied animals also floating about in the primordial pond had much more hidden evolutionary potential and it could be that they simply hadn't expressed all that they were going to be in the future - as yet. The fossil record clearly shows such creatures and I will discuss these in more detail in part two. In the meantime, below are several quotes describing the many varied ways in which modern day microbial life-forms behave, which might just give us an insight into how these comparatively primitive organisms became majorly complex forms akin to, but no less dramatic, as Margulis's micro-mergers.

An illustration of the role of synergy in the evolution of complex systems can be found in sponges, one of the simplest multi - cellular organisms in the natural world... Although sponges come in many different sizes and shapes, the "model" sponge looks more like an urn or a vase than your typical kitchen sponge. Sponges are also the most rudimentary of all animals in terms of complexity. Indeed, they are often confused with plants because they are immobile and have no internal organs, no mouth, no gut, no sensory apparatus nor even a nervous system. They are more like a colony of cooperating independent cells. Sponges even have their own separate classification (Porifera, or "pore - bearers"), and they may have evolved separately from other animals.

- (Corning 2013, 15).

http://journals.isss.org/index.php/proceedings56th/article/viewFile/1932/658

The point about the above quote is that sponges are more like a colony of cooperating cells and may have evolved separately from other animals. Furthermore, they are actually so primitive that they have similar attributes to a complex, but still rudimentary form of organism – plants. Rudimentary animals don't even require features that we would presume were required to make it an animal. Could sponges represent an ancestral condition in the process becoming more complex? And that some rudimentary animals just had more genetic/metabolic in-built complexity that allowed them to go further on their evolutionary development? Now returning to the colony of cooperative cells, for example, a recent study shows that some slime-moulds can complete a maze in record time, yet it has no brain, no mouth, or specific body form.

Slime Mold Smarts

The slime mold Physarum polycephalum is a single cell without a brain, yet it can make surprisingly complicated decisions... slime mold navigates through a maze and solves a civil engineering problem.

- (Rothschild & Jabr 2012, Nova Science).

Meet the Microbes

"During good times, they live as independent, amoeba-like cells, dining on fungi and bacteria. But if conditions become uncomfortable — not enough food available, the temperature isn't right, etc. — individual cells begin gathering together to form a single structure. This happens when the cells give off a chemical signal that tells all of them to gather together. The new communal structure produces a slimy covering and is called a slug because it so closely resembles the animal you sometimes see gliding across sidewalks. The slug oozes toward light.

When the communal cells sense that they've come across more food or better conditions, the slug stops. It then slowly does a kind of headstand. Cells in the slug now begin to do different things. Some of the cells form an anchor for the upended slug.

Others in the middle of the slug begin making a stalk and some at the tip turn into what's called a spore cap and others become spores in that cap. When a drop of rain or strong wind knocks the spore cap hard enough, the spores go flying out. These spores are like plant seeds. Each of them becomes a new amoeba-like cell when they land and each goes off on its merry way"

(American Society for Microbiology 2006).

http://archives.microbeworld.org/microbes/protista/slimemolds.aspx.

Can Answers to Evolution Be Found in Slime?

Some experiments show complex choreography of signals in some species that allow 20,000 individuals to form a single slug-like body. Some species gather by the thousands to form multicellular bodies that can crawl. Others develop into gigantic, pulsating networks of protoplasm.

(Zimmer 2011 New York Times October 3rd)

http://fission.sas.upenn.edu/caterpillar/index.php?action=retrieve&article=Slime%20Molds%20-%20Ancient%2C%20Alien%20and%20Sophisticated%20-%20NYTimes.com.pdf

This reminds me of Hebb's law, which would begin to account for the way in which cellular colonies communicate and don't forget the property of undifferentiated cells that act like memory foam when working and resonating together. For instance, in Science Daily an article entitled: 'Scientists control rapid re-wiring of brain circuits using patterned visual stimulation' outline the following regarding Hebb's law:

"Hebbian Theory," named after the McGill University psychologist Donald Olding Hebb who first proposed it in 1949 has been confirmed in real-time experiments as reported in a science paper on neurology (2014) and confirmed the axiom: "Cells that fire together, wire together. Cells that fire out of sync, lose their link."

- (Science Daily May 28, 2014)

http://www.sciencedaily.com/releases/2014/05/140528104953.htm

In other words, there were potentially an awful lot of quiet eruptions of new and novel forms even before the eruption of more complex life are recognisable in the fossil record which is particularly obvious during the first major epoch known as the Cambrian explosion dating to almost half a billion years ago, which I will discuss and attempt to explain in the light of the above in part two.

The research of Margulis and others therefore helps us understand the ancestral conditions and means of speciation in the earlier stages of evolutionary complexity in combination with the epigenetic species adaptations according to environmental triggers, orchestrated according to universal growth laws guiding the growth and development of the organism via its developmental context (morphic field) or external environment in the case of cooperating colonies of cells.

Margulis is also famous for her criticism of the rather rigid proclamations of our Modern Synthesis: Furthermore, mutations don't appear to bring about a new species, just deformed or dead things and population modelling used by the Neo-Darwinists has been described as numerology as seen in the following quotes by LYNN MARGULIS. But before going there, perhaps I should highlight what Richard Dawkins' views are on her scientific contributions:

I greatly admire Lynn Margulis's sheer courage and stamina ... This is one of the great achievements of twentieth-century evolutionary biology...

— Brockman (1995) Chapter Seven

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QUOTES BY ~ LYNN MARGULIS ~

...When evolutionary biologists use computer modeling to find out how many mutations you need to get from one species to another, it's not mathematics—it's numerology.

*— Teresi (2011, 71) 'Discover Magazine' April Edition**

**This is slightly different to the online version linked above ~ original online source link at discover.cloverleaf.com now defunct.*

Neo-Darwinists say that new species emerge when mutations occur and modify an organism. I was taught over and over again that the accumulation of random mutations led to evolutionary change [which] led to new species. I believed it until I looked for evidence.

*— Teresi (2011, 68) 'Discover Magazine' April Edition**

Mutations, in summary, tend to induce sickness, death, or deficiencies. No evidence in the vast literature of heredity changes shows unambiguous evidence that random mutation itself, even with geographical isolation of populations, leads to speciation.

— *Margulis & Sagan (2008, 29) 'Acquiring Genomes: A Theory of the Origins of the Species'*

... Then how did one species evolve into another? This profound research question is assiduously undermined by the hegemony who flaunt their correct solution. Especially dogmatic are those molecular modelers of the tree of life who, ignorant of alternative topologies (such as webs), don't study ancestors..., they correlate computer code with names given by authorities to organisms they never see! Our zealous research, ever faithful to the god who dwells in the details, openly challenges such dogmatic certainty.

— *Margulis (2006, 1) 'The Phylogenetic Tree Topples'*

Darwin's big mystery was why there was no record at all before a specific point [dated to 542 million years ago by modern researchers], and then all of a sudden in the fossil record you get nearly all the major types of animals. The paleontologists Niles Eldredge and Stephen Jay Gould studied lakes in East Africa and on Caribbean islands looking for Darwin's gradual change from one species of trilobite or snail to another. What they found was lots of back-and-forth variation in the population and then—whoop—a whole new species. There is no gradualism in the fossil record.

— *Teresi (2011, 68) 'Discover Magazine' April Edition**

CHAPTER EIGHT

MUTATIONS BY ANOTHER MEANS?

Fig. 21 Portrait of Hugo De Vries [Public Domain via Wikimedia Common]

Hugo De Vries

(1848 – 1935)

Dutch botanist and one of the first geneticists.

Hugo De Vries (a Dutch Botanist and early geneticist) proposed a very different form of mutation or whole species remodeling in one fell-swoop. His research and Mutation model of evolution (not as the meaning of genetic mutation we use today), was based upon years of experimentation with hybrid plant species, and observations of: *"..., spontaneous alterations of genes that yield large modifications of the organism and give rise to new species. According to de Vries, a new species originates suddenly, produced by the existing one* *without any visible preparation and without transition".* (Ayala and Fitch 1997, 7692). http://www.pnas.org/content/94/15/7691.full.pdf

In a nut shell: De Vries' theory and several other distinctly different theories, rejected gradualism and the idea of selection. For De Vries, gradualism was certainly not the way nature produced species, as borne out by his years of studies and experiments. The Modern Synthesis (Neo-Darwinian version) meaning of genetic mutations came to mean something entirely different to what De Vries had originally proposed. Furthermore, he argued that natural selection did not have the power to produce new and novel variations and in some cases was actually detrimental to evolving a new species. This is clearly documented in the review of De Vries' Mutation Theory in the journal SCIENCE dating back to 1910:

It has long been recognized that natural selection really explains, not the origin of species, nor even the origin of adaptations, but the elimination of the unfit, and the persistence of adaptations; the fact that characters, both adaptive and non-adaptive, specific or not specific, must exist before they can be selected was previously well nigh lost sight of. The mutation-theory, then, seeks to account for "the origin of specific characters" (p. 211). In the second place, "Spontaneous variations are the facts on which this explanation is based" (p. 45), or, "We may express the essence of the mutation theory in the words: 'Species have arisen after the manner of so-called spontaneous variations'" (p. 165). This marks the fundamental distinction between Darwinism and de Vriesism. ... from the standpoint of the theory of mutation it is clear that the role played by natural selection in the origin of species is a destructive, and not a constructive one." ... Mutations are characterized first, by being entirely new features, "In contradistinction to fluctuating variations which are merely of a plus or minus character (p. 213); second, by the abruptness with which they appear, and third, by being transmitted by inheritance' without selection. They arise suddenly and' without any obvious cause; they increase and multiply because the new characters are inherited"

------ 'Science', (May 13th 1910, p. 741)

http://www.jstor.org/stable/pdf/1634773.pdf?acceptTC=true

Our modern synthesis has consistently rejected leaps in complexity as a real fact of the fossil record. And Darwin's species problem (how one species changes into another), remains unresolved as noted in 'Resynthesizing Evolutionary and Developmental Biology'*: "The origin of species — Darwin's problem — remains unsolved"* - Gilbert, Opitz, and Raff (1996, 361), http://www.evolbiol.ru/large_files/gilbert.pdf

Even after the well-founded rejections of gradualism and selection in relation to speciation by De Vries and other geneticists, botanists, embryologists and via experimental work in general around the turn of the 20th century, the modern synthesis eventually came to reject all things non-selection-based and certainly would not tolerate anything that suggested leaps of speciation, or anything that was environmentally determined (Lamarckian type acquired characteristics known as acquired characteristics and becoming widely accepted in modern science under the broad label of epigenetics as discussed earlier.

De Vries and many others before and after his time, had problems with the Darwinian concept of gradualism and selection, and indeed, even within the ranks of true Darwinians (adhering to Darwin's original concepts that are perceived as less rigid than the gene-centred model upheld by ALA: Richard Dawkins), there has been some controversy regarding gradualism and even the strictest form of selection (see quote books for issues with the entire modern synthesis and natural selection and gradualism in particular). For instance, attempts to address the obvious gaps and lack of transitional forms and sudden eruption of new and novel forms of species within the fossil record, led to a theory based around stasis (meaning stability, presumably as an attempt to keep it broadly within the Darwinian tradition) with the occasionally leaps (punctuated parts) proposed in the 1970s Gould and Eldredge known as the punctuated equilibria model of evolution where environmental factors were considered important to these occasional punctuated parts. This was and still is, a seriously tame version of De Vriesian evolution, but just to give you an insight into the manner in which this was considered as part of the Neo-Darwinian synthesis, which it was, but it was referred to by Richard Dawkins ***as "a minor wrinkle on the surface of the neo-Darwinian theory*** "(Dawkins 1986, 254).

The theory of punctuated equilibrium will come to be seen in proportion, as an interesting but minor wrinkle on the surface of neo-Darwinian theory. It certainly provides no basis for any 'lapse in neo-Darwinian morale', and no basis whatever for Gould to claim that the synthetic theory (another name for neo-Darwinism) 'is effectively dead'. It is as if the discovery that the Earth is not a perfect sphere but a slightly flattened spheroid were given banner treatment

under the headline: COPERNICUS WRONG. FLAT EARTH THEORY VINDICATED.

- (Dawkins 1986, 254-255) 'The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe without Design'

http://bikerman.co.uk/images/audio/science/Blindwatchmaker/files/basic-html/page255.html

This rejection of gradualism is somewhat irrational, I believe, in the light of the well established arguments for the leaping nature of the fossil record and from what could be observed via embryological studies; these giant leaps in whole complexity are certainly more than a wrinkle and these major monumental speciation events had been long understood by many evolutionary scientists, especially anyone working on hybridation with plants and anyone working in embryology in particular, if they were paying attention. Furthermore, our present emerging understanding of the molecular mechanisms that can bring about profound leaps of complexity that have been identified via many recent studies can no longer be ignored.

All of this of course supports the main tenet of De Vries's concept of leaping evolutionary complexity is much better supported than the selection or gradualistic model. As it turns out however, although De Vries did not fully understand what was causing all of this leaping, he did what any good scientist does: he observed and studied and set up experiments that could reveal the unknown aspects of evolution itself. It perhaps didn't fundamentally matter that unbeknownst to himself, what he was observing was another form of genetic exchange that is perhaps more familiar to most of us than the means described above regarding horizontal gene transfer and microbial mergers and the mating rituals of yeast or jumping genes that do their own genetic engineering. This is hybridisation which is more common than you might have imagined between even unrelated species and must have contributed significantly to evolutionary complexity in the past. As the article below outlines, De Vries actually had come inadvertently to discover hybridisation as an important factor in speciation:

In the history of evolutionary biology, Hugo de Vries is known as a proponent of the mutation theory of evolution, in which new species are believed to arise by single mutational events ... This theory is based on the breeding experiment he conducted for 13 years with the evening primrose Oenothera lamarckiana and its mutant descendants. In this experiment, he discovered a number of phenotypic variants, which bred true or segregated variant types in addition to the parental type...he unknowingly found the importance of polyploidy and chromosomal rearrangements in plant speciation.

http://gbe.oxfordjournals.org/content/3/812.full.

Yes, isn't interesting that the plant species he was working on was called after Lamarck. The concept of hybridisation is not seriously considered within the Neo-Darwinian synthesis as one means of speciation and not thought to be of any great significant in the context of natural selection by Darwin as discussed in a recent science paper highlighting the influence of one of the leading lights of our modern synthesis: Ernst Mayr. As the paper outlines:

Mayr ... rejected any idea that hybridization might contribute to adaptive evolution, especially hybrid speciation. Furthermore, because in 1942 he was concerned only with animal speciation, and animal chromosomes were still poorly known, he was able to argue that speciation by any sort of polyploidy was in essence absent (Mallet .p. 13. Mallet on Mayr and Darwin

http://www.ucl.ac.uk/taxome/jim/pap/Mallet_on_Mayr%26Darwin08.pdf

But these days we know better as seen below. Even as far back as over 200 years ago and indeed before this time, hybridisation and its role in creating new species was discussed and observed in nature and had begun to be explored as a means of evolutionary change. For instance below is a quote relating to the importance of hybridisation as a means of evolutionary change by Jean Baptiste Lamarck, who I mentioned earlier regarding our modern concept of epigenetic evolution and whose theory clearly proposed a naturalistic mechanism and an obvious relationship between higher primates and humans:

1809

- Jean-Baptiste Lamarck -

'Zoological Philosophy...'

Translation by Hugh Elliot 1914

(first trans., from French into English)

The idea of bringing together under the name of species a collection of like individuals, which perpetuate themselves unchanged by reproduction and are as old as nature, involved the assumption that the individuals of one species could not unite in reproductive acts with individuals of another *species. Unfortunately, observation has proved and continues every day to prove that this assumption is unwarranted; for the hybrids so common among plants, and the copulations so often noticed between animals of very different species, disclose the fact that the boundaries between these alleged constant species are not so impassable as had been imagined.*

— Lamarck (1809, 39)

https://archive.org/stream/ZoologicalPhilosophy/ZoologicalPhilosophyAnimals_Lak_506pgs51391278#page/n129/mode/2up

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~ New York Times ~

'HYBRIDS MAY THRIVE WHERE PARENTS FEAR TO TREAD'

DNA analysis is now allowing biologists to better decipher the histories of species and to detect past hybridisation events that have contributed new genes and capabilities to various kinds of organisms including, it now appears, ourselves...The discovery of hybrid species and the detection of past hybridizations are forcing biologists to reshape their picture of species as independent units. The barriers between species are not necessarily vast, unbridgeable chasms; sometimes they get crossed with marvelous results.

— Carroll (2010) 'New York Times' 13th September Issue

http://www.nytimes.com/2010/09/14/science/14creatures.html?_r=0

'ORIGIN & EVOLUTION of ANIMAL HYBRID SPECIES'

The increasing number of hybrid species, discovered in both vertebrates and invertebrates ..., calls for a reevaluation of hybrid speciation and reticulate evolution in animals... Unexpected similarities are now apparent in hybrid evolution of animals as varied as insects, snails, fish, frogs and lizards.

— Bullini (1994) Abstract

http://www.sciencedirect.com/science/article/pii/0169534794901244

Caterpillars evolved from onychophorans by hybridogenesis

I reject the Darwinian assumption that larvae and their adults evolved from a single common ancestor. Rather I posit that, in animals that metamorphose, the basic types of larvae originated as adults of different lineages, i.e., larvae were transferred when, through hybridization, their genomes were acquired by distantly related animals.

- (Williamson 1990)

http://www.pnas.org/content/106/47/19901.full.pdf

Yes, well you can imagine what sort of trouble this scientist got into for that proposition. Not all scientists rejected it – it is pretty interesting though. Margulis noted earlier, was instrumental in even letting him offer it as a hypothesis based upon a life-time of research. I thought it might be interesting to review Williamson's proposal in the light of more recent studies in epigenetics. As the except below explains, metamorphosis reflects the differential expression (different programs activated at different times) – it is an epigenetic phenomenon - of the same genes at different times and metamorphosis could have indeed been an important means of becoming entirely different looking organisms during their species development in the evolutionary past if we follow Von Baer's laws of different expressions of forms according to environmental and adaptive needs, then Williamson may have been unto something, but that this genetic novel exchange (HGT, mergers and/or some type of hybridisation) may have occurred long before the larvae-like organisms had reached their full adult species form. They don't have to express their adult potential until the conditions are just right – i.e., there is no point in becoming a flying insect if the flowering plants haven't evolved from plant life in general that had colonised the land and it is really all timed according to adaptive needs.

Evolution would appear to be all about co-evolution as plants need insects and insects need plants. Perhaps the slug-like creatures were fed up eating algae and decided that moving unto land and eventually expressing genes differently to make wing fibres would be a great way of flitting from flower to flower, eventually, when some slug-like colony of cooperating cells that finally decided to wire together and become more than it could be as a loose collection of bits and bobs of microbial life had grown up to be fully-fledged species and when they reproduced, their larvae would go through the old ancestral programs or perhaps skip these altogether or revert to them again if the need arose as pointed out within the quote below:

Metamorphosis is an amazing example of the dexterity of animals to switch to different development programs. This certainly contradicts the prevailing opinion that an egg or a zygote provided with a program that determines development up to the adult stage. This gains more significance when one remembers the ease with which some metamorphosizing amphibians can switch to a direct mode of development, or even skip metamorphosis altogether. It is possible that the same egg/zygote contains the programs for two different Bauplans, and sometimes even a program for skipping its species-specific Bauplan? Metamorphosizing species, besides their own developmental program, have incorporated and executed ancestral developmental programs.

Amazingly, like biological Houdinis, they shift the gears of development both forward (insects and amphibians) and backward (ascidians).

Cabej (2013, 179)

The vast genetic exchange across all domains of life, whether via HGT, mergers, mating microbial life, or hybridization as seen in the eukaryote forms of life (plants and animals) are in a sense hybridisation at all scales of life. The result is the same: rapid and profound speciation in one fell swoop, just as De Vries had inadvertently observed. When we add into this genetic novelty mix, the rearrangement of existing genes (via jumping genes – which can remodel the organism's genome) and the epigenetic programs that operate those genes, the concept of cells firing together and communicating and the idea of cellular memory and their growing/development environment, all ultimately guided by laws of growth and form – thereby, generating meaningful adaptations in accordance with environmental conditions, begins to give us an alternative means of species change.

This is a much more dynamic form of evolutionary development than our conventional model of selection and genetic mutations allows. It also gives us a means of adaptive differentiation from a common ancestral condition (a shared body plan that can be expressed in many different ways) that diverge over time according to their experience as proposed by such people as: Lamarck, Von Baer and D'Arcy Thompson, which is gaining increasing support in the light of our more modern understanding of biological complexity.

All in all, the ancestor may not have been an actual tangible entity, but rather a process, a shared ancestral condition that coordinated itself into meaningful cellular life as seen in the colony of synchronised cells, and as others have suggested, the tree may have had many roots and its branches are more web-like than we could imagine. It seems that epigenetics in its ability to turn genes on or off, silence or activate ancestral programs or regulate the degree of genetic expression according to chemical cues which are environmentally-triggered, has a great deal to do with how all the genetic novelty (via HGT, mergers and/or hybridization) provides the mechanism for meaningful adaptations.

How else does a flower know not to bloom in winter? Species formation would have been no different. A fully adapted (blossoming) species would not display all its genetic potential until the conditions were just right. Do these seasonal programs give us an insight to their evolutionary programs activated according to major environmental shifts (seasons on a much grander evolutionary timescale)? If so, a flowering plant is perhaps displaying its grand ancestral stages of evolving on a condensed scale of development within its own life-time. A more complex organism such as you or I may also be replaying (on a miniature scale within our own life-time), our ancestral modes of evolutionary development; going from our cellular, embryonic, fetal, infant, adolescent and finally, our fully matured adult form. This is of course, is the pattern one would expect if we were following Von Baer's laws of development. This is applied here and as you will see in part two, it really does correspond well with what we see in the fossil record.

As an introduction to Book Two, I would like to quote one of my favourite poets, William Blake (1757 – 1827) in his opening lines of 'Auguries of Innocence':

"To see a World in a Grain of Sand
And a Heaven in a Wild Flower
Hold Infinity in the palm of your hand
And Eternity in an hour..."

This is the type of fractal thinking on every scale of complexity required for Book Two when we begin to apply the nuts and bolts processes and more overarching principles offered by the scientists over the last 200 years (as discussed above) as their theories, principles and observations, supported by an increasing body of more modern studies, begin to form a cohesive whole and fully comprehensive alternative evolutionary theory when assessed and applied to what we already know.