# Engenetics
## The science of species

## The four laws of biology

As of May 2010, Stacey Herald of Dry Ridge, Kentucky, USA, is the world's smallest mother. With a height of only 2' 4", 71 cms, she was no taller than the average three year old when she gave birth. She was so small during her pregnancy that her belly protruded so much that she was almost as wide as she was tall. The weight of her developing foetus was also so great, compared to her own, that she could not stand up and was confined to a wheelchair for most of the nine months. In spite of all concerns, she successfully gave birth to her first daughter. But although very small to have delivered a child, Mrs. Herald still had to go through a period of growth, development, and maturation before being able to conceive. Although many people believe they know exactly what these processes are, the growth of biological entities is actually a very subtle concept, and its consequences need to be handled with care. Even many famous professional biologists do not conceive of, or handle, the idea correctly!

It is not, for example, strictly speaking accurate to say that the earth "has" an atmosphere … not unless the object and topic of discussion has been clarified. The atmosphere in fact belongs to the entire planet. So the more correct relation is: planet = earth + atmosphere. We can then say: planetary mass = atmosphere's mass + earth's mass. And since there is life on earth, then we can extend this to say planetary mass = atmosphere's mass + earth's mass + mass of all biological life forms. It does not matter how many biological entities exist, or die, or are born. The planetary mass is left unchanged throughout. The SETI initiative (Search for Extra-Terrestrial Intelligence) applies gravitational analysis to detect the specific gravitational signatures in the perturbations of alien galaxies, solar systems, and suns that indicate the likelihood that a suitable exo-planet exists—one that might support liquid water, and therefore Earth-like life forms. A team of Swiss, French and Portuguese scientists using the ESO 3.6-m telescope discovered such a planet in April 2007. But any candidate exo-planet's mass, along with its gravitational behaviour, remains the same whether biological entities in fact exist upon it or not. None of that affects its gravitational behaviour in the least. What this means is that we need to look at something besides mass if we want to properly discuss biological entities and populations.

When a cow grazes in a field, the cow's mass increases by the quantity of grass consumed … while the earth's mass decreases by exactly that same amount of grass. As is elucidated in the experiment with *Brassica rapa*, or field mustard (sometimes also called 'fast plant'), described on the engenetics web site [http://www.engenetics.net], then from a scientific perspective we have to be careful to do the correct kind of book-keeping. We have to make sure that we direct our attention to the correct phenomena. The planetary mass has remained unchanged all the time the cow has been grazing. That planetary mass did not change when the cow was born, and it will not change when the cow gives birth and subsequently dies. This may all seem obvious, but forgetting this has frequently gotten even the most experienced working scientists in trouble on more than one occasion. But if mass is inadequate, then what are we to consider instead?

When a biological entity appears to increase in its mass and grow, it can only do so by going through two steps. Firstly, it has to unbind or detach a given quantity of chemical components from the earth. That deprives the earth of those self-same components and reduces its mass. The cow can only do this by exerting energy. If we want to "explain" the cow correctly, then both that energy and that mass of chemical components have to be carefully accounted for. The method for achieving this is clarified in the experimental data available on the engenetics web site [http://www.engenetics.net]. Secondly, after having thus acquired a suitable set of chemical potentials—for that is precisely what it has done—the biological entity must go through a series of chemical reactions and bind those newly extracted components to itself for its own usage. This again takes a suitable quantity of chemical bonding energy … which must again be recorded and analysed. Both the mass and the energy must be accounted for, and the one cannot be properly considered without the other. The method for doing this important kind of book-keeping is also discussed in the experiment with *Brassica rapa* made available on the engenetics web site [http://www.engenetics.net].

Now that the biological entity of record has properly incorporated the extracted components into itself, it can exploit the set of chemical pathways it has at its disposal—thanks to its DNA and its own physiology—and metabolize them. All the while, however, the planetary mass is left unchanged. Throughout the entire process of the growth, reproduction, and death of the billions of biological entities on earth, the planetary mass and gravitational behaviour remain constant. The earth's mass, however, oscillates wildly through the innumerable micro-increases and micro-decreases of mass imposed upon it through the chemical binding energies and metabolic processes deployed, at any given moment, by biological entities as they hunt, graze, photosynthesize, reproduce, excrete and die. Mass itself is extensively dealt with in other sciences. Engenetics focusses on the associated variations in chemical potential. (It also makes no signal or relevant difference to an engenetic analysis if, as could arguably be the case with some prokaryotic organisms, mass either does not, or else barely, increases within any specified organism in a clearly definable growth phase. From a population perspective, chemical components must still be acquired before new organisms can be created. This takes both mass—which simply represents the chemical components needed—and energy. Further pertinent analysis is made available on the engenetics web site [http://www.engenetics.net]).

Viewed from this perspective, then there are two different aspects to the whole growth and development process. Small as she was when she eventually gave birth, when Stacey Herald was herself born, she did not have the chemical potential necessary to allow her to reproduce. She still had to do two things: she first had to grow, even if only modestly; and she then had to develop and go through puberty. Therefore, the overall processes engenetics is interested in have two importantly different aspects:

1. A quantitative aspect in which the total number of chemical bonds available to a given biological entity (or population thereof) increases. This is an increase in the entity's chemical potential. The method for measuring this increase is explained in detail in the analysis of the experiment with *Brassica rapa* that is made available on the engenetics web site [http://www.engenetics.net].

2. A qualitative aspect in which those bound chemical components are reshaped, transformed, and exploited along a variety of different chemical pathways. These various pathways are all implied in the acquired chemical potential. The method for measuring this is also explained in detail in the experiment with *B. rapa* made available on the engenetics web site [http://www.engenetics.net].

The science of engenetics is concerned exclusively with the behaviour of chemical potentials as indicated above. It is very easy to get caught up in the concept of growth as a "simple" increase in mass. Engenetics, however, proceeds with the clear understanding that mass itself is not the relevant dimension when it comes to biology. Engenetics, as a biological science, is instead concerned with the chemical processes of biological entities. There are those chemical processes that are current at any given time, such as in essential cellular respiration; and there are those processes for which given organisms continue to have the as-yet-unexpressed potential. This gives rise to the important distinction between the quantitative and the qualitative aspects of chemistry and chemical potential. It is important to keep firmly in mind that the growth of biological organisms in fact represents an increase in their chemical potential. This is the quantitative aspect. The qualitative aspect of chemical potential shows itself in the repair, development and the like of biological organisms. The increased chemical potentials made available in growth are then being exploited in ways that benefit the entity—and/or its species. After all, not even Stacey Herald, small as she was, could reproduce without first completing the quantitative stage, and so increasing her chemical potential. As all biological entities do, she did this by continuously binding to herself an ever-increasing number of chemical components. And only when the chemical potential that those chemical components represented had attained a sufficient magnitude—i.e. only when she had reached puberty—could she then undertake the necessary qualitative changes that allowed for reproduction. Reproduction expressed and exploited the implied acquired chemical potentials.

Now that we have suitably clarified the role and importance of chemical potential, we are in a position to declare engenetics' **first law of biology**. Although the law uses the word 'mass', it is to be clearly understood that it is no more than a compact reference to the above concept of 'implied chemical potential’. It is simply counterproductive to invent a whole new word when clarifying the meaning of an old and otherwise perfectly serviceable one will suffice. But since the first law of biology is concerned, through mass, with chemical potential and the energies of chemical potential, we have immediately strayed into the province of thermodynamics. The first law of thermodynamics declares the existence of energy; states its basic properties; and underlines its complete equivalence in all its various forms. Engenetics’ first law of biology should do the same for biology. This means elucidating the pertinent and essential properties of biological entities. Since a biological entity is a nexus of chemical potentials; and since those chemical potentials must, at the very least, keep that entity firmly separated from the environment and in an orderly (or low entropy) state so that it can survive and go through its designated cycle of biological activity; then that immediately gives us the parameters that need to be stated by any proposed first law of biology.

When a given thermodynamic system does what science closely defines as work (which has a special meaning in science), that work done can be detected, in the environment, through the movements of material bodies in space and time, and as the relevant energy is absorbed and/or released. Whenever a biological entity either preserves or increases its chemical potential, it extracts components from the environment. The conditions surrounding the establishing of the first law of thermodynamics assert that it is in principle possible to divert the chemical potential of a biological entity, which is more technically called its sensible enthalpy, into a device—the details of which do not have to be specified—that can then support some given weight, at some given height, in some given gravitational field. Therefore, as you sit where you are reading these very words, it is in principle possible to imagine yourself being attached to some unspecified battery, or other device. This can slowly drain all the energy out of you; siphon it off into a pulley system; and then keep some material object floating above the surface of some planet somewhere in this or any other galaxy. This can be continued until all the energy is drained out of you and you are fit for no more than a coffin or cremation. At that point, the weight of the moment will fall under the gravitational attraction of that said planet. If a species is going to be viable, then it is mandated that all the entities of which it is at any time composed at some time increase their chemical potentials, jointly or severally, so that, as Stacey Herald did, the species can reproduce. All these considerations lead neatly to engenetics' declaration of the first law of biology:

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**LAW 1: There is an entity such that it must always lift a weight; and such that it must, and by this means, at some time increase in its mass.**

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Although the first law of biology identifies an important property that all biological entities possess, we do know that they all live in species. Biological entities—and species—may show marked differences, but the entities within any one given species share a similarity or equivalence. They can also reproduce and produce further entities which show the same equivalence. We therefore need a way of characterizing their chemical potentials, both acquired and implied, so that their similarities are made explicit and they can be allocated to the relevant populations and species. The renowned Scottish physicist James Clerk Maxwell, 1831–1879, made some extremely important contributions to thermodynamics. By the time he came to study it in any depth, thermodynamicists had already identified three axioms or laws which they used to unify and simplify their subject. Although the first law already existed, Maxwell realized that a very important first step, prior to that, had been omitted. They had failed to properly identify the nature of what they then called "heat power", but that we now call temperature. It was clear that substances exerted "heat power" on each other in a search for **mutual stable equilibrium**. However, there was no way to identify when, and how, that state had been attained. Since the requirements for the end to the process of searching for mutual stable equilibrium should logically have been set out before the three laws extant had been discovered, Maxwell's new law is sometimes allocated the number zero and so is sometimes referred to, in the literature, as the zeroth law of thermodynamics. But since it was in fact the last one to be discovered, it is much more commonly called the fourth law of thermodynamics. Maxwell said that temperature or heat power represents the mutual exchange of heat energy between systems. That granted, then equality of temperature should be defined as the state in which no further such exchanges occur. The fourth (or zeroth) law of thermodynamics then states that if the three substances *A*, *B*, and *C* are in the requisite state of mutual stable equilibrium with respect to each other, such that they donate energies and all other required thermodynamic properties to each other all in equal measure, then $T_A = T_B = T_C$ and they all have the same heat power, or temperature. They can be freely substituted for each other in all pertinent interactions involving heat energy.

By the above first law of biology, when two biological entities have the same chemical potential, then they can support the same masses at the same heights in the same gravitational fields. Engenetics now transforms Maxwell's fourth law of thermodynamics into its similarly formal statement of biological equivalence by suggesting that if two biological entities, or populations, have the same mass and chemical potential at all times across the relevant time periods and generation lengths so as to allow them to contribute and to partake in similar age distribution populations and behaviours, and all while doing the same quantity of work, then they are equivalent. They are substitutable for each other in all interactions involving energy, both the biological and the non-biological. Their masses and the quantities and energies of the chemical bonds composing and deployed by them from one moment to the next are equivalent. They are now going through the same energy interactions at the same masses, and at the same rates. Based on this recasting of the fourth law of thermodynamics, the second law of biology reads as follows:

**LAW 2: If a first entity can follow a path such that Law 1 is satisfied; and if a second entity can follow the same path to the same effect; then the first and second entities are equivalent.**

Charles Darwin's observation that, in any species, the young outnumber the old is the backbone of evolutionary studies. It simply must be incorporated into any realistic attempt to create laws or axioms for the biological sciences. Population figures confirming Darwin's observation are provided in the experiment with *Brassica rapa* made available on the engenetics web site [http://www.engenetics.net]. However, the essentials of the argument can be presented using data from a 5-year study conducted on a species of grasshopper, *Chorthippus brunneus*, by the the British field researchers O.W. Richards and N. Waloff in the fields around Ascot, Berkshire, United Kingdom. *Studies on the biology and population dynamics of British grasshoppers*, 1954, Anti-Locust Bulletin, 17, pp 1-182. Richards and Waloff saw the *C. brunneus* population initially increase; collapse under environmental stresses; and then increase back to previous levels. This indicates that in its equilibrium age distribution population, each *C. brunneus* adult will participate in the production of 22 fertilized eggs. The activities available to each egg, immediately after fertilization, are greatly limited. Not one of them is as yet capable of reproduction, although each has the potential to do so, if only it can beat the severe odds stacked up against it and survive to adulthood. Each of those 22 fertilized eggs represents a probable path through the system … and each has as good a chance as any other of becoming that successfully reproducing adult. As the cycle of the generations proceeds, each *C. brunneus* entity that is still surviving, at any given moment, is increasing in its chemical potential. It is also increasing in the scale of activities available to it. As time passes and biological entities follow the first law of biology and increase in their chemical potentials, human infants that at first could not even left their own heads, never mind stand, become able to do not just that, but much else. Plants that at first could not photosynthesize or build bark become able to do so. When Stacey Herald was born she was incapable of reproduction, and so also with the grasshoppers. In all cases, as biological entities increase in their mass—and thus in their chemical potentials—they become capable of things that were previously impossible to them. But as these chemical potentials and scopes of activities increase, so also does the number of surviving entities decrease. But that is not the only consideration. Another important factor that any proposed law of biology needs to take properly into account is that although, for example, both worker and queen ants and bees increase in their respective chemical potentials and scales of activities, they do not all undertake the same kinds of activities. Some are sterile and will never reproduce. To express this situation slightly more formally, then each path remaining available to the system increases in its energy, over time, even as the number of such remaining paths steadily declines, while paths that were previously hard or impossible to find become available, although not necessarily selected, due to the increases in energy and chemical potential. And now that we have expressed the situation in this way, it suddenly becomes possible to formally express a law of biology encompassing all relevant criteria.

Although James Maxwell had succesfully defined equality of temperatures with his fourth (or zeroth) law of thermodynamics, the renowned U.S. theoretical physicist, chemist, and mathematician Josiah Willard Gibbs, 1839 –1903, realized that there were still some gaps in the overall theory. He made two important contributions. Firstly, he explained how water, for example, could change from ice, to liquid, to vapour. These are known in the discipline as phase transitions. Gibbs explained them through his Gibbs phase rule and Gibbs triple point. His other important contribution was to point out that although Maxwell had indicated the importance of systems striving to attain mutual stable equilibrium, he had not in fact indicated why they should do this. What mechanism forced thermodynamic systems, of different temperatures, to seek for mutual stable equilibrium and to equalize those temperatures? How did that process work? The German physicist and physical chemist Walther Hermann Nernst, 1864–1941, took up an interest in this very topic, and eventually provided a much more rigorous restatement of the third law of thermodynamics. Nernst turned his attention to what happened to a system when energy was removed from it and its temperature was insistently lowered ever closer to the absolute zero of temperature. He pointed out that a very important difference in behaviour arises between those interactions that can do useful work and those (such as the heat wasted in friction) that cannot. Not only do these differences between work and nonwork interactions become increasingly important, but so also do the differences between what thermodynamics calls allowed paths and allowed states and required paths and required states. As the temperature of a system is lowered, then the paths that will allow its temperature to be lowered yet further become increasingly hard to find. If such a path does exist and that could lower the temperature yet further, then it will take increasing effort, and increasing quantities of energy, to find and traverse it. And the closer we get to absolute zero, the harder it gets. Thus the number of allowed paths decreases, even as the energy required to traverse them increases. The third law of thermodynamics more formally states that 'the entropy of any finite system approaches a non-infinite value as the temperature on the Kelvin scale approaches zero'. As the temperature of a system is taken ever closer to the absolute zero of temperature, it will demonstrate a specified minimum finite value for its entropy. But the third law of thermodynamics also indicates what happens if we move in the other direction, away from the absolute zero of temperature. Although the third law requires of all systems that they demonstrate a minimum finite values for their entropy as they tend towards absolute zero, it is nevertheless allowed to them to decrease their entropy, at any time, without also decreasing their temperature. This is what happens when liquid water turns to ice. We are far away from the absolute zero of temperature, and temperature has remained constant while the stock of energy in the system has decreased. The resulting phase change has instituted both a volume and an energy change, and the system's chemical potential has increased. So while the third law of thermodynamics requires a minimum and finite value for entropy, it permits entropy to increase when temperature either rises or remains the same … meaning that thermodynamic systems can undertake interactions of increasingly divergent types. Substances are thus different because they increase their entropies at different rates for each increase in temperature and/or heat energy. Therefore, when the temperature of a system rises, the number of allowed paths and states tends to increase, while also becoming much easier to find. Ice melts to become water because paths that were previously unavailable have suddenly become available at that same given temperature of zero degrees Celsius. Liquid water is the more active and energized state and will be differentially adopted above zero degree Celsius, with that temperature being the point of transition between the solid and liquid phases (depending on the conditions and the amount of energy available).

And with this clearer understanding of required and allowed paths, we can now try to formulate the proposed third law of biology. *Chorthippus brunneus* begins its cycle with 22 fertilized eggs per adult precisely because the probability of survival is low. To put it another way, the path of reproduction is very hard to find, and therefore demands this greatly increased quantity of energy otherwise the species will fail to be viable. Every *C. brunneus* adult that successfully breeds represents the only one out of the originally 22 available and equally probable paths that has managed to navigate the system. And in order to ensure species survival then it must successfully meet the requirements of the engenetic burden of fertility placed upon it, and it must itself provide 22 fertilized eggs. In a fashion that is completely analogous to that created for thermodynamic systems by the conditions of the absolute zero of temperature, every successfully breeding *C. brunneus* adult represents the path that has been increasingly hard to find as the chemical potential of the system has changed. Each one has become the increasingly less probable, and therefore more energy intensive, path. Once again, the *C. brunneus* population provides itself with 22 such paths because the path of reproduction sought by them all is equally hard to find, and demands ever increasing—but finite—quantities of energy to traverse it. The closer a given population gets to reproduction, then the less the number of allowed paths—i.e. entities—remaining to it, but the greater is the chemical potential represented in those paths. They can all do more work in the environment, and achieve greater effects. And since a biological population must at all times respect Law 1 it must both possess mass and constantly do work. Each biological entity is in other words the physical manifestation of a probable path through a biological system. Those paths then proceed to diminish in number as the progeny is lost until only a given number of progenitors remain, any one of which might successfully reproduce due to its increased chemical, and of course biological, potential. As per the first law of biology, certain things are required of all biological entities such as the preservation of a minimum chemical potential through such acts as respiration and excretion. Those must therefore form a part of the first law of biology. Others, however—such as courtship activities, growing horns, or developing sex-specific structures and plumage—are allowed, but are not required of all. They come under the remit of the second law of biology, because they can still be used to classify species on the basis of similarity. And with this distinction between the required and the allowed in place, Charles Darwin’s observation that the young outnumber the old, and that they share with the old an equivalence of mutuality in replacement, leads neatly to a reworking of the third law of thermodynamics as the required third law of biology:

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**LAW 3: The sum of all the paths that satisfy Law 2 constitutes the allowed set for the entity and its equivalents; while that which permits them to satisfy Law 1 constitutes the required set.**

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The Scottish inventor and mechanical engineer James Watt, 1736–1819, successfully improved the original Newcomen steam engine out of all recognition and thus facilitated the Industrial Revolution. Nobody, however, could really understand why it worked quite so well, so most attempts to improve it were unsuccessful. The French physicist Nicolas Léonard Sadi Carnot, 1796–1832, decided to determine its theoretical principles. He set himself to determine, in technical language, if there was some upper bound to heat power. In much the same way, Charles Darwin observed that no living organism's population ever grew indefinitely, even though every organism known produced more young than survived. That is to say, he observed the existence of an upper bound to the reproductive capabilities of all living organisms. He then set himself to understanding its nature and consequences. It is probably initially surprising to be told that Carnot and Darwin were in fact asking themselves exactly the same question. It is only necessary to do for biology what Carnot did for the steam engine, and establish a suitable model for this to become self-evident. The specifics of the model, along with the experiment with *Brassica rapa* that validates it, are made available on the engenetics web site [http://www.engenetics.net]. Carnot's mathematical model established a limit phenomenon—a physical condition towards which all real physical systems could tend, but that none could ever attain. Carnot's model was so successful that he used it to announnce the existence of a previously unknown property of nature. He suggested it should be adopted as a new law. He declared that heat always flows from a hotter substance to a colder one, and that it can never travel the other way. Later researchers, most particularly his fellow countryman Rudolf Julius Emanuel Clausius, 1822–1888, developed Carnot's original insight into the concept of entropy. Carnot's mathematically derived and unattainable limit phenomenon thus moved on to become the bedrock of the present-day understanding of the physical universe. It is enshrined in physics as the famous second law of thermodynamics which declares the existence of entropy … and … it is this very law that links the seemingly separate topics studied by Darwin and Carnot irreducably together.

James Maxwell's fourth law of thermodynamics says that when systems are in suitable thermal contact with each other they will jointly seek for mutual stable equilibrium. Mutual stable equilibrium is therefore a property of several systems conjointly. But these separate systems clearly cannot seek for a mutual stable equilibrium unless each one separately—and at all times—seeks for its own particular, and isolated, equilibrium. And … establishing the behaviour of isolated systems in regards to their search for an independent stable equilibrium is the business of the second law of thermodynamics. This is a special and distinct state. It has specific and identifiable properties that set it apart from all others available to that system. The law achieves its purpose by announcing the existence of entropy. This is an indicator of the overall state, or condition, in which a substance or system may be found. The second law all but establishes thermodynamics as a distinct subject by pointing to the existence of this unique phenomenon that is its unique preserve—and yet that is held in common by all its chosen objects of study. And since its domain of discourse is all objects that use or are composed of energy, then its domain is the entire universe. The second law of thermodynamics can be stated as follows:

> Among all the allowed states of a system with given values of energy, numbers of particles, and constraints, one and only one is a stable equilibrium state. Such a state can be reached from any other allowed state of the same energy, numbers of particles, and constraints, and leave no effects on the state of the environment.

If engenetics is to achieve its purpose, then it must similarly point to some phenomenon that is uniquely possessed by all biological populations. It must also be something that uniquely stamps them out as biological. Any putative fourth law of biology must emulate the second law of thermodynamics and announce the existence of some unique property that is not, and cannot be, possessed by any other objects whatever that also use energy.

We can begin by noticing that a mathematician such as Carnot establishes a model by circumscribing, through a precise use of language, the essential properties of whatever may be the objects of study. We can then further notice that both the second and the third laws of thermodynamics achieve their purposes by distinguishing between allowed and required paths and states. This is clearly the way to proceed.

Although populations of biological entities have it in their power to maintain a stable equilibrium population, they can only do so by constantly abiding by the first law of biology. They must constantly do work and be able to maintain given masses at given heights in given gravitational fields. Should they cease to do this, at any point in the cycle of the generations, then their components will degrade and will be returned to the environment, adding to the earth's overall mass. But by the second law of thermodynamics—and, just as importantly, by the first maxim of ecology—it is impossible for any biological entity, even in an ideal case, to maintain its chemical potential indefinitely. In the fully generally case, therefore, the biological cycle of the generations must bestow upon some second entity, *B*, all of the properties and the potentials that were at one time possessed, at that equivalent point in its own cycle, by some first entity, *A*, that has subsequently been lost. Included amongst the properties that must be transferred from *A* to *B* should be all those properties that were at one time only in potential possessed by *A*; are not at any given moment realized by *A*; but that are nevertheless potentially realizable by the *B* that has replaced it. Every path allowed to, and required of, *A* must be re-established for *B* such that *B* can in its turn do the same for some successor biological entity *C* that will likewise follow it … and so on and so forth. It is fortunate indeed for any entity seeking to be biological that earthly DNA has precisely this property. The details of the model that establishes such a cycle are stated on the engenetics web site [http://www.engenetics.net].

The third law of biology, derived just above, performed the signal service of grouping all the activities in which biological entities are wont to engage into the required and the allowed. It is required of every population that wishes to remain viable and avoid extinction that its members follow those paths whose net result is to increaese their chemical potentials by increasing their mass. But although all entities are required to absorb and maintain chemical bonds and mass, they are not all required to follow the same paths—least of all the procreative ones that would seem to mark out entities as uniquely biological. If a given species is to survive, however, then while it may not be required of any particular entity that it in itself reproduce, it is required of all those that share an equivalence that they somehow and conjointly arrange for this to be done. Two different things are therefore required of the entities constituting a given population. As stated in Law 1, and as confirmed in Law 3, they must at all times maintain mass, and must at some time increase it. But if the equilibrium age distribution is to be maintained then the entities must conjointly do work—over and above any required activities—to ensure the production of suitable numbers of their progeny. These acts must therefore form a subset of the allowed set of activities enumerated in Law 3. So just as the second law of thermodynamics requires that one, and only one, of all the states allowed to a thermodynamic system in any given state be the stable equilibrium one associated with that state; then so also is it required of a given species or population that at the very least one, but allowably more than one, of all the paths contained in its allowed set must be the path that transfers suitable propensities from *Entity A* to *Entity B*. There must in other words exist a property of the entire population and the whole biological cycle taken conjointly … but that need not be the property of any one entity or any single point in the cycle when taken severally. Thus a minimum of two entities is required to establish a suitable biological cycle. One is the donor of the requisite properties; the other is the recipient. The biological cycle is then immediately the property of both considered together, and is not the property of either one taken separately. The energy demanded by this specific path is the energy required to prevent—as a bare minimum, and even in the ideal case—the extinction of the population in the face of the deleterious effects imposed by the second law of thermodynamics. In a real case, and as elucidated on the engenetics web site [http://www.engenetics.net], there are other such countervailing forces to contend with. This property now alluded to by the proposed fourth law of biology can be formally called reproduction. As is required, it is unique to biological entities. It is the method they use to defeat the inexorable maw of the second law of thermodynamics; and it is the method they use to strive to assert the continuance of the given species or population. Any thermodynamic system utilizing this property is immediately biological, and any thermodynamic system enjoying the title biological immediately utilizes this property. Therefore, and finally:

**Law 4: In the allowed set is at least one path such that mass is surrendered, and such that a further entity possessing the required set, and satisfying these four laws results.**

And when these four laws of biology are combined with the **three principles or constraints**, and the **four maxims of ecology**, they complete the set of irreducible axioms that establish—and bring a necessary rigour to—the biological sciences, and as is discussed and demonstrated on the engenetics web site [http://www.engenetics.net]. They in particular help to demonstrate the impossibility, even in abstract form, of those theories proposed to explain biological entities but that are centred on the premise of the everlasting and unchanging fixity of species The argument explicating this is available on the engenetics web site [http://www.engenetics.net].

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