Chapter 2

[NOTE: This chapter is a relic of a superceded book plan, and can be skipped or read lightly.]

To predict how life will change over time we look for what changes very slowly and therefore is in a position to channel life's direction. Stone cliffs can channel the direction of a river's flow because stone cliffs change slowly relative to the rapid movement of flowing water.

To ease consensus, in our search for the relatively changeless we favor the tangible and mutually observable – the physical in other words – things like stone cliffs, average distance between neighbors, and the average movements of organisms. If the *un*observable channels evolution then we can never prove it, because any mutually acceptable proof amounts to a mutual observation of the unobservable (a contradiction).

We also allow ourselves to *induce* constraints on life's unfolding. If all observed living things behave as if their behavior is constrained in a particular way then we may guess that the constraint is essential to life and guides the history of all life.

Three induced regularities offer an excellent starting point in our search for physical constraints on life's unfolding:

1. All living things die and must gather to themselves and their near-copies various forms of matter and energy, some with informational structure, in order to persist longer and stave off death.[1]
    a. Life thus depends on causal chains and loops, where *causal* here means that one element in a link regularly precedes the other.
    b. With a nod to the taint of teleology, the needed matter, energy and information may be called *external resources*.
2. All living things are composed of and possess finite stores of matter and energy, again with informational structure.
    a. These may be called *internal resources.*
3. All living things reproduce: They persist in the long term only by making exact or near-copies of themselves.

Other regularities can be induced but these three are very basic and, significantly, they already point a general direction to life's unfolding.

If every organism needs external resources in order to persist then an organism whose internal resources happen to cause the intake of the external resources needed for survival and reproduction will persist longer (including by way of progeny) than a like organism whose internal resources cause such intake only poorly or not at all. This yields the following prediction:

[1] Bacterial endospores that remain dormant yet viable for millions of years cannot be verified as living until they begin guiding resources to themselves and copies.

Causality Prediction: Life evolves in the direction of organisms whose internal resources cause the guiding of external resources toward and into themselves and their near-copies. The target of this intake shifts on average from self toward copies over the course of an individual organism's lifetime.

Does this prediction meet the standards of scientific rigor? The prediction can be tested in a number of ways, and per the demands of science, potentially can be falsified.

One test of the Causality Prediction is to sample any organism and test whether the organism's use of internal matter and energy can speed the intake of external resources to itself (first) and to near-copies (later). If inhibiting the organism's use of internal matter and energy has no effect on resource intake, or on its persistence, and this is observed in many cases, then the prediction is falsified.

The Causality Prediction carries within it the seed of a further important prediction, one that bears not only on the emerging Sparseness Adaptation Theory, but on a larger theme of this book (more precisely of *Dragon Puzzle Story*). We have predicted that all organisms must use their internal resources in order to guide external resources toward themselves and their copies. For life to persist there must be a net return on the investment of internal resources, a return ultimately taking the form of progeny. It follows that any organism that gains a higher return of external resources in exchange for a lower expenditure of internal resources – or that causes formerly unused matter and energy to become new life-sustaining resources, relative to comparable neighbors, will accrue a larger number of progeny. This leads to the following:

Efficiency Prediction (provisional): Life's evolution is biased in the direction of organisms that more efficiently use internal resources to gather external resources to themselves and their near-copies, and that more efficiently cause formerly unused forms of matter and energy to become new life-sustaining resources.

The fact that many of an organism's traits are adaptive already speaks of efficiency: There are many traits any organism does *not* have, and it is notable that most of the absent traits likely would cost resources to sustain, and they would bring few resources in return. Lacking these traits amounts to a form of efficiency.

At this point I detour to the promised larger theme, catalysis.

Overture on Catalysis

What is a catalyst? In early use *catalyst* referred primarily to substances that affected the rates of chemical reactions while emerging relatively unchanged themselves. This early use is familiar in the action of enzymes. These proteins occur in myriad varieties that speed and slow the chemical reactions in all living organisms. Enzymes control virtually all chemical reactions in the human body, including for example the breakdown of starch to sugar, in the mouth, by the enzyme *salivary amylase*. Enzymes speed or slow

chemical reactions and emerge from each reaction relatively unchanged.

The principle of catalysis can be generalized far beyond the actions of chemicals: **A generalized catalyst is *any* thing that changes another thing or process while emerging relatively unchanged itself.** In this respect the genetic material DNA is a generalized catalyst. Here I refer not only to DNA's effect on simple chemical reactions, but also to the fact that it speeds the building of large living structures while emerging relatively unchanged itself. The net effect of DNA's catalysis is the sculpting of entire organisms.

An ideal catalyst does not change at all in the course of its affecting events. However, real catalysts degrade or otherwise change slowly with time even while retaining power to affect events. That is why the forgoing description of a generalized catalyst speaks of "emerging *relatively* unchanged". A generalized catalyst is not an abstract ideal but rather a gradually changing, decaying thing of the everyday physical world,.

In the provisional Efficiency Prediction we see predicted an evolutionary bias toward organisms that return more resources while using fewer. To return more external resources is to affect the motion and change of external things, while to use fewer internal resources is to change less. In other words, the second prediction prescribes an *increasing catalysis*. Because it also provides for the possible development of novel resource flows – forms of *innovation* – the prescribed increase in catalysis is more accurately described as *developing* catalysis. The Efficiency Prediction may therefore be renamed and rewritten in this simpler form:

Catalysis Prediction: Life's evolution is biased in the direction of developing catalysis.

Combining the Causality and Catalysis Predictions we have that life is biased in the direction of developing causal loops and chains that guide resources to *auto*catalysts and their near-copies.[2]

Can a prediction this terse and general possibly be scientifically rigorous? This is a non-trivial question and it raises a host of practical, ethical, and categorical problems. I do not intend the Catalysis Prediction as the definitive rejoinder to Darwin's predictive weakness, but rather as an overture to later discussion of catalysis in the Dragon Puzzle. The Catalysis Prediction is the smoke to a later fire. That said, it does have some predictive power:

Chemical catalysis is routinely measured in laboratories, presumably by means considered rigorous. The Catalysis Prediction can be tested in principle by exhaustively measuring organism *general* catalytic capacity in an ecosystem, by whatever means is deemed rigorous, then waiting a long time – perhaps even thousands or millions of years

[2] Where originals and copies are effectively interchangeable, causal chains guiding resources to near-copies alone are effectively autocatalytic.

– and repeating the measures on descendants. If there is no upward trend in the average or maximum measures then the prediction is falsified.

Catalyst's-eye View of Genes and Groups – resolving an old debate

Viewing life in terms of developing catalysis largely resolves a longstanding debate. The words *gene*, *genome*, and *organism* are often used interchangeably, thus inconsistently implying that each is the primary unit of reproduction and evolution. The conclusion that "life is biased in the direction of developing causal loops and chains that guide resources to autocatalysts and their near-copies" offers the reconciling view that gene, genome, organism, and group are all potential *parts* of a greater autocatalytic process.

Recall that a generalized catalyst is any thing that changes another thing or process while emerging relatively unchanged itself. A very powerful catalyst then is as slowly-changing as a diamond-like crystal while myriad causal chains pass through it. By the present reasoning life's evolution is biased in the direction of developing autocatalysis. If so then life is biased in the direction of stable units through which pass innumerable causal chains and loops. Other things being equal, the denser the packing of causal loops in the stable unit the more powerful the autocatalyst. The bias in favor of *developing* catalysis requires stable units that are not perfectly crystalline, but allow for slow change to themselves. These properties pretty much describe DNA and nothing else yet on Earth, and so in the present view DNA represents a pinnacle of autocatalysis on Earth. To the time of this writing DNA holds the place of honor on Earth as the central reproductive and evolutionary autocatalyst.

The idea of a causal link or causal chain may seem too vague to admit of scientific rigor. Notice how subtle causes can be! Green eyes or even a freckle can make all the difference to the reproduction of DNA. Nevertheless, without plain or subtle causality there is no science. Fortunately, just as one doesn't need to count the grains of sand in a cup in order to know that two cups hold almost exactly twice as many, so also one doesn't need to name and count all causes in order to satisfy the demands of scientific rigor.

There is no autocatalysis without causal loops, and so any regular links in the chain of an autocatalytic loop are in a real sense a part of the autocatalyst. In the case of DNA those links include epigenetic modifications, RNA, myriad enzymes, membranes, the structures of the organism within which the DNA sits, and also any regularly-present neighboring group of organisms, or even slowly-varying organic and inorganic resources in the environment. That is quite a list, and it is not exhaustive. **It is essentially arbitrary where one marks the bounds of a reproducing, evolving autocatalyst.**[3] It's like marking the boundary of a whirlpool. It is fair then to speak of genes, genomes, organisms, groups, and so on, as evolving reproductive units as long as one acknowledges their joint role in an autocatalytic system, and takes care to avoid accidental intellectual sleight-of-hand.

[3] This is also why I do not attempt to base the present reasoning on speculations about *fitness*.

Although the exact boundary of an autocatalyst is arbitrary there is within living systems a hierarchy of elements, extending from the stable and causal-chain-dense to the more volatile and less chain-dense. The stable part is like the rocky core of a planet, wrapped in more volatile seas and air. Alternatively the stable part can be compared to a tree trunk connected to more changeable roots, branches and leaves.[4] In most organisms this hierarchy proceeds from DNA through RNA, enzymes, membranes, organism structures and on to groups of organisms. The boundary of an autocatalyst may be arbitrary, but in most discussions it contains first the more stable elements of the autocatalyst – its DNA or equivalent.

There is much more to be said about autocatalysts, not least that the elements of an autocatalytic loop, like a human hand or green eyes, are often if not usually autocatalysts themselves. However, we now continue the search for predictable trends in life's unfolding.

Diverging Innovations

For the most part, predicting a bias toward increasing catalysis is about as controversial as predicting that a person who does not waste money and who figures out how to make money selling stones is likely to end up richer than a spendthrift twin who sees no value in rocks.

A great difficulty in testing catalytic trends is in comparing organisms that have diverged radically from a remote common ancestor, each following a different path of innovation. If humans descended from something like an ancient bacterium, and modern bacteria at all resemble the common ancestor of modern bacteria and humans, then this highlights the problem. Both bacteria and humans exist today: Does a human brain have no more catalytic capacity than an equivalent mass of bacteria? How can the catalytic capacities of the two be compared? A single brain can compose a book, and a single bacterium can decimate the human population on Earth. It seems to be a problem of "comparing apples and oranges", as the saying has it. This problem is taken up later in study of the Dragon Puzzle.

The earlier story of the Little Dutch Boy highlights the importance to life's history of unpredictable events like meteor impacts and falling trees. Even such unpredictable catastrophes do not necessarily reverse a trend to greater catalysis: On the contrary, it is the organisms that use resources most efficiently, and that are able to find new resources among wreckage, that are most likely to persist.

Recall that we are not seeking absolute, clock-like predictions but rather predictions like a weather forecast. The Causality Prediction seems likely to be nearly absolute, but the Catalysis Prediction is more statistical. It's a bit like a prediction about the effects of gravity: Objects on Earth do not always move downward, but what is up usually does

[4] These metaphors are superior to that of nested matryoshka dolls because the solidity of the outer dolls does not capture the volatility common in the outer regions of a living autocatalyst.

come down. In evolution there is a bias favoring organisms whose internal resources more rapidly cause intake of external resources to themselves and near-copies, with decreasing expenditure of internal resources. The arc of evolution may be long, but it bends toward catalysis.

The Causality and Catalysis Predictions are major predictions about the course of biological evolution. In passing I now briefly mention two others, less prominent, to aid later discussion.

An organism that happens to key its use of resources to its present circumstances is thereby more catalytic than it otherwise would be: Having the ability to use a resource, but reserving that use for contexts that bring a return of fresh resources, causes significant external change with minimal internal change – the signature of catalysis. This leads to the following:

Context-Dependence Prediction: The more generations an organism is exposed to change between different recurring conditions the more the organism's resource use will become context-dependent. In each condition an organism will come to use more those resources that have aided it in the present condition and use less those that have aided it only in conditions not present at the time.

If few creatures ever altered their use of resources in response to changing circumstances, particularly after generations of exposure to alternating conditions, then this would falsify the Context-Dependence Prediction.

A prediction can also be made about the average *rate* of evolutionary change. The Causality Prediction tells that an organism's persistence depends on its use of resources, including its structure and regular behaviors – its traits – and that these traits are adaptive, i.e. linked to the organism's circumstances. Many circumstances change slowly, for example the presence of earth, gravity, air and daily light. Evolution of any kind implies change, but life first depends on organisms for the most part *not* changing radically or rapidly over generations. Life would soon end if each non-fish gave birth only to fish in one generation, to potatoes in the next, and so on. An organism's traits effectively are a memory of past conditions and a prediction that future conditions will resemble them. This yields the following:

Adaptive Inertia Prediction: Organism traits that have changed only very slowly over generations, or not at all, will rarely if ever change rapidly. This is particularly true where the traits allowed an organism to survive conditions that changed only slowly or not an all.

If species commonly gave birth to different species in a single generation then this would falsify the Adaptive Inertia Prediction. However, if this happened rarely it would not falsify the prediction. Adaptive Inertia is consistent with (though not strictly dependent on) the Darwinian expectation that most large changes are the result of many small changes accruing over time, so that a large change is unlikely to reverse suddenly.

In sum, four predictions about the future courses of biological evolution – the Causality, Catalysis, Context-Dependence, and Adaptive Inertia Predictions – were made and shown to be falsifiable.

Observation and reasoning lead to this conclusion: EITHER there is no increased probability of survival to be had in increased efficiency and innovation, even in the face of want and competition, and likewise no penalty for waste and failure to innovate in the face of death, OR life's evolution has a general direction – and that is an exclusive OR. This direction points to developing catalysis but also raises the problem of its definition in cases of divergent innovation, a problem deferred to later discussion about the Dragon Puzzle.

Significantly, the four predictions make no appeal to an organism-building "watchmaker" beyond the seemingly impersonal forces revealed by observation and reasoning. However, this stand-in for a "watchmaker" is not blind: To repeat, it provides that *evolution has a general direction.* If the predictions are not falsified then they predictively augment Darwin's predominantly retrodictive theory of evolution. We now proceed to more decisive predictions about life's unfolding.