THE DARWINIAN EVOLUTIONARY THEORY AT ITS FACE VALUE

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Abstract

Darwin (1859) published his Evolutionary Theory (ET) lacking a mechanism for inheritance. So, it is incomplete as a white-box, mechanistic theory. Nevertheless, the Darwinian ET is complete as a black-box theory, one that specifies functionality. We furnish it with a faithful genetic implementation. This allows a quantitative comparison with the current ET that blends the ideas of Darwin with molecular genetics, a lead sparked by Mendel. The two theories are found to be very different: the Darwinian ET is miraculous, as expected by Darwin, while the current ET shows how difficult to battle complexity is for Evolution.

1 INTRODUCTION

Darwin ([2] 1859) published his Evolutionary Theory (ET) to explain the origin of species. Later, Mendel presented his experiments with peas in 1865 (Griffiths [8] 2000). After a long delay, his ideas sparked a research trend that can be seen today as molecular genetics, the science of mechanistic inheritance through genes The ideas of Darwin were blended with the genetics of Mendel in the Synthetic Theory (ST), a modern version of the ET that was formulated around 1930. Its formulation is currently equivalent to Population Genetics (Jorde [11] 2016).

The ST provides a mechanism for inheritance so, it is a white box theory. Its overdevelopment has caused the original thought of Darwin to be dismissed. Nevertheless, it seems to us that the Darwinian ET is complete as a black-box theory, i.e., as a formulation of overall results but without a mechanism. We propose here a faithful genetic mechanism for the Darwinian ET to compare it next with the ST. As expected by Darwin, his theory is miraculous. By contrast, the ST slowly shows us how difficult to battle complexity is for Evolution.

2 THE EVOLUTIONARY THEORY

Every human being has the sacred duty of reinventing the ET: it is enough to see how strikingly similar the skeletons of a human being and a bird are. One is a deformation of the other. So, the ET states that human beings and birds are brothers in the very sense of biological reproduction.

But to be brothers does not explain by any means why the bird so wonderfully lands and why we, human beings, are so intelligent.

A great effort to sustain a theory that pretends to explain this and more is in great measure due to Charles Darwin.

2.1 The Darwinian ET

Darwin learned from geologists that there were changes in the fossil record along the geological strata and that these were gradual. This was an observation. Next, he observed by himself, say, in the Galápagos Islands, that changes in trait frequencies can happen within months in response to environmental modifications. These and tens of other facts were intertwined in a theory.

The Darwinian ET has many ingredients, some proved to be wrong, but those that were shown to be indispensable can be summarized as follows:

1. Variability: among organic beings in a state of nature there is variability in many, many traits. The variability of the human race is so high that the faces of some men are astonishingly similar to those of some monkeys.

2. Inheritance: like begets like in reproduction despite some differences.

3. Death is a fundamental component of life. Darwin deeply experienced this in his heart when his beloved daughter Anne Elizabeth died when she caught scarlet fever. In general and as stated by Malthus, more offspring are born than can survive because they are checked by famine, disease, and depredation (war for the human case). But surviving is not at random. Instead:

4. Natural Selection: Traits are tied to surviving in a given environment and so, individuals with some inheritable traits that can reproduce better than others make those traits to be popularized.

5. The more generations are passed, the more rounds of selection for the best are executed, and the more perfect become those traits that are important for differential surviving. A permanent source of variability is assumed.

The mechanism to create variability was unknown to Darwin and the beliefs of the time were unfavorable because inheritance was supposed to rely on the blood that was imagined to be blended along with reproduction. The mechanism came from a monk that converted the garden into a lab.

2.2 The legacy of Mendel

Seven years after Darwin published his work, an article by the monk Mendel was also published. It remained in obscurity for some 30 years and Science needed some other 30 years to mature the perception of its importance.

Mendel was an idealist that tried to accommodate field data to what he thought. His idea was that the traits of his peas, to have purple or white petals, correspond with discrete items that are passed on to the next generation. Those discrete items are called now genes with the problem that they can be passed on but not necessarily expressed showing that gene regulation exists and works. In that way, he showed that complexity is inherent to life.

The lead sparked by Mendel and which is known today as Molecular Biology has explained both inheritance and variability. Inheritance is explained by saying that the genome, the overall content of the DNA, is copied from parents to offspring. On the other hand, the copy procedure is not exact and includes random changes or mutations in the DNA that modify the corresponding traits creating variability.

2.3 Complexity and perfection

The extreme complexity and marvelous perfection of life strike every person and are at the root of most religious beliefs. Explaining them is a priority for Science. Let us see the form as the ET explains them. The idea was formulated by Darwin and remains invigorated today.

Complexity is understood here as the property of an object whose structure needs a long document to be described. On the other hand, perfection deals with function. Say, the function of the eye is to see and I, being an old man, continuously marvel at the present functionality of my eyes despite troubles with vision at a distance. When I get depressed, I thank the Lord for my eyes, and tricks like this return me peace and joy.

Regarding complexity, considered documents are strings in binary format, consisting of zeroes and ones. Although binary strings are very specific, no generality is lost because each string of whatever nature and with whatever information content always can be encoded as a binary one. This fact has allowed the universality of memory and computing chips that only deal with zeroes and ones. These strings are generically called passwords. In gradualism, they can be matched or guessed step by step, bit by bit.

The existence of extremely finely perfect organs, like the eye, was challenging for Darwin. But after many years of work he proposed a solution:

To suppose that the eye, with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree. When it was first said that the sun stood still and the world turned round, the common sense of mankind declared the doctrine false; but the old saying of Vox populi, vox Dei, as every philosopher knows, can never be trusted in science. .. Reason tells me, that if numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade being useful to its possessor, can be shown to exist; if further, the eye does vary ever so slightly, and the variations be inherited, which is certainly the case; and if any variation or modification in the organ be ever useful to an animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, can hardly be considered real. How a nerve comes to be sensitive to light, hardly concerns us more than how life itself first originated; but I may remark that several facts make me suspect that nerves sensitive to touch may be rendered sensitive to light, and likewise to those coarser vibrations of the air which produce sound.

Thus, the solution proposed by Darwin is gradualism, to gather small progress from generation to generation. Assuming that Evolution never halts, this is what he expected in the long term:

As all the living forms of life are the lineal descendants of those which lived long before the Cambrian epoch, we may feel certain that the ordinary succession by generation has never once been broken, and that no cataclysm has desolated the whole world. Hence, we may look with some confidence to a secure future of great length. And as natural selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection.

It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the conditions *of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone circling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.*

So, Evolution + Gradualism was for Darwin a sufficient, convincing, and aesthetic explanation of life in all its folds of complexity and perfection.

2.4 Darwinian ET is a black-box theory

The TE of Darwin is incomplete because it lacks a mechanism for heredity. Now, this accusation is correct from the stand of white-box theories. In them, the mechanism must be exhaustively specified. Nevertheless, his theory is complete, even redundant, as a black-box theory, one that declares the overall behavior without going into detailed mechanisms.

The salient characteristic of the Darwinian TE is that Evolution is a killer of complexity and that is why the mechanistic detailing of evolutionary transformations is irrelevant. This is exactly what Scientists seem to believe even today. So, no one is worried about reproducing the transformation of the fins of a lungfish or its ancestor into the limbs of, say, a frog.

Let us discuss a bit the meaning of complexity and its killing. It happens that we all are experts in complexity. It is the air we breathe every instant. Just consider my own experience concerning music:

I was educated by my father to despise music because at that time a musician was at risk of starving. Nevertheless, as soon as I could, I took some private classes to play the recorder with the help of scores because my musical ear was the worst in the world. Next, I tinkered with pianos, a violoncello, keyboards, and a flute. I even got secure enough to play in the services of the church and teach children and adults. For me, it has been extremely difficult to pass the level of beginner, but after years and more years of informal practice, one can do some things that attract the attention of others. Now, how long would I need to play as well as a young teacher of music that I got acquainted with 2 years ago? To be sincere, I would need to be born again. The problem is that I play very slowly, out of tempo, with no adornments, no complexity, no art. Nevertheless, I have been working in a new way of accompanying he taught me. That would mean great progress. But, two years of work and I cannot as yet employ it in a service.

One might argue that I have no evolutionary importance. Hence, let us think of my young teacher. He was born amidst a musician family in the church. So, he received continuous and intensive training even before birth. No surprise that he is now spectacular. The problem with my appreciation is that I am not an authorized judge. Instead, he applied to a professional school of music, was admitted, and that was for him a great triumph. The fact is that he is not for himself a great master. Indeed, he gave me a link to a video of the professional musician that he admires. He explained to me the recursive technique that that artist uses to improvise. His dream is clear: I would like to someday play like him. But, excuse me: I do not see a great difference between him and that admired professional.

1 ***General conclusion.*** *Perfection can be mimicked, approximated in too many ways, and it is extremely costly to ascend along any of those many graded paths. So, one can find specimens that remain ecstatic in a given state, battling during an eternity for progress but with no real improvement. The more near to perfection, the harder is to improve. In short: under-perfection abundantly predates perfection.*

If we transcribe this to biological complexity, it reads: We are very complex and highly functional. To be complex means that many approximations exist that are mediocre or low-quality products. Hence, these will be found earlier than perfection. Therefore, if we were the result of Evolution, tracks of imperfection would be bountifully found not only in the fossil record but also in our bodies. Where are they? Nowhere. That is why the ET is obviously false.

That is complexity in subjective terms. Now, **can the complexity be killed?** I would say that Science (mathematics plus clever experiments) is the most powerful method of killing complexity. So, killing complexity is possible. And, what about the Darwinian ET?

2 ***Concourse.*** *Create the best implementation of the Darwinian ET that fairly represents its black-box specification of making Evolution into a killer of complexity. Our proposal is presented in the next section.*

Because we are discussing fundamental questions, a warning is welcome.

2.5 Theories must be tested

The purpose of Science is to formulate theories to be tested. This is done by devising crucial experiments. If results coincide with what is expected, the theory survives and more clear-cut tests are invented. When the theory fails, a new one is invented by modifying the extant one or by creating a new insight. And so on. In that way, Science gets stronger thanks to an Evolutionary Process that never gets sick of making more questions. These ideas are due to Popper (Shea [10], 2015?).

Real Science tolerates the most severe contradictions, say in Physics (Weinberg, [13], 1989). Regarding Biology, the ET is shielded from the aforementioned falsifying procedure because if the ET is menaced, Creationism wins points. And this is intolerable for Materialism, which functions as a regulatory philosophical directive. So, what might be the purpose of studying the fundamentals of ET? It is to help everyone to understand what he or she believes in.

3 NON-DISSIPATIVE GRADUALISM

We will present a faithful white-box implementation of the gradualism of Darwin. Because it is mechanistic, we need a problem to test its power. Guessing words, sentences and ideas has proven to be a very interesting problem. It acquires a biological meaning if we ask: Who or what did guess the DNA of my genes? Guessing games have been common since the beginning of time in all cultures. Example:

3.1 The wise wrath of the King

What kind of king do you think I am? Everyone spoke well, all but one woman that remained muted. She was Ia, the beloved daughter and personal assistant of the First Minister. So, the King addressed her by name, and at once the Minister fainted. She said: You are a very bad king because the poor get poorer and the rich get richer. In reaction, the Chief of the Army anxiously demanded her to be executed and so did everyone in the sequel. The King agreed. Yes: he agreed. By that time the First Minister already had recovered his senses and asked to grant her an opportunity: Let her guess the way as she should die. I grant her 70 lives, the King responded and wrote the death sentence on a roll. So, she was given 70 opportunities to guess the way she should die. She recalled 17 and invented 53 more, but she failed. So, she was given the roll and commanded to read it aloud:

I condemn you to die of old.

To comply with the sentence of the King and after deliberation, bodyguards and doctors were assigned to her. After many years she died of old enjoying the respect of her enemies and the love of the people of the earth for whom she so much good had done.

So, **guessing words is a complex problem. Can its complexity be killed?** Yes. There is a very popular game that employs a powerful strategy to attenuate complexity.

3.2 Hangman

To target complexity to children and language learners a very precious game of guessing words has been devised that is called Hangman. It is played by two persons, the Judge, and the Gamer.

Main rules of Hangman:

1. The Judge thinks of a Target Word, and the Gamer has to guess it by voicing a series of letters.

2. If the Gamer proposes a letter and it is in the Target Word, the Gamer proposes another letter. If it is not in that word, the Judge adds a segment to a stick figure hanging from the gallows.

3. The game ends when the Gamer completely matches the Target Word else when the Judge finishes with his hung man. In the first case, the Gamer wins, but in the second, the Gamer loses. The Judge never wins.

You are invited to play this game in Internet (Horton [7] 2013?)with your children. To study the code, use the program `Hangman.html` that accompany this file. Now, all kids and teenagers of the world love this game. So, it is not that difficult. Why? Because it uses something very interesting!

Complexity killing technology of Hangman:

- Hints can be given that restrict the target word to a set of, say, fruits, wild animals, or cities.
- A word is a string, which is ordered. In this game the order is forgotten, the only thing that matters is whether a char is in the word.
- All instances of a char are guessed with just one shot. In short: the game simplifies the problem by supplanting a string with a set.
- Once a char is proposed, it is classified by the Judge as correct else incorrect and this classification is eternal and always visible to the Gamer. So, the effective alphabet of source chars is shortened with each shot. Thus, the game does not propitiate setbacks or repetitions.

3 ***Concourse.*** *Use the technology of Hangman or whatever to devise a complexity killing algorithm to match strings using Evolution. Our proposal follows. We will deal with the problem of matching an ordered string and as a killing strategy, we use only the fourth point of the previous list.*

3.3 Implementation

Evolution can succinctly be described as follows: If something does not function, make a change. This is a mutation. To enhance variability combine different solutions to produce a third. This is a recombination. Pick the best solutions and select them to perfect them further. This is a selection.

In nature, mutation and recombination are executed by the cellular biochemical machinery while selection is the overall process in which some individuals with certain traits systematically succeed better than others in surviving and reproducing.

Selection is a global abstraction that depends on the interaction of the individual as a whole with its environment as a whole. Selection is not written anywhere. It is an interaction that depends on entire organisms. Nature sees a hand and how useful it is but not the DNA that encodes for it (Is the hand encoded in the DNA?). So, genes and their bases are hidden from selection. Nevertheless, a titanic effort is currently made by scientists to associate the characteristics of individuals with specific versions of groups of genes. This task is by no means easy and that is why the battle of Science against terrible diseases like cancer is so slow. By contrast, Hangman says publicly and forever that a pronounced char is or is not in the target word. To be or not to be is a certainty that is expected to accelerate the Evolutionary Process and whose real power we will gauge here.

We are ready now to test our algorithm as a complexity annihilator. This algorithm is called non-dissipative because it gathers small progress that is never damaged, corrupted, or stained.

Non-dissipative gradualistic algorithm:

1. Start with one string generated at random. Detect the matched sites and freeze them.

2. Apply random mutation to unfrozen sites (those that are incorrect), detect correct chars, and freeze them. Do this recurrently.

3. Stop when every site is matched.

3.4 Cost

Let us inquire over the cost of matching a password with Non-dissipative gradualism.

Example. Let us suppose that we need to match the string 101010. It represents the information for that something that so much marvels us, like an eye. The initial string generated at random is 100101.

Evolution:

101010 target word
100101
Our string matches 2 sites which we freeze.
101010 target word
- - 0101
Unfrozen sites are replaced by random binary chars. The result is:
101010 target word
- - 1100
Two new sites have been matched. They are frozen:
101010 target word
- - -10 -
Things remain alike in a new round of mutation:
101010 target word
- - -10 -
Then, one more site is guessed
101010 target word
- - -11-
Matched site is frozen:
101010 target word
- - -1 - -
A new round of mutation:
101010 target word
- - -0- -
Task ends.

We say that the cost of matching the target word is 5 because we needed an initial setting plus 4 modifications, making a total of 5 individuals. After all, each new round of mutation could be understood to have been made over a clone of the last individual.

When the string is short we expect an almost immediate solution but the larger is the string, the more and more generations are expected to be needed to match

the target. But, how many? We need general results that must be found by extrapolation from simulations. Our algorithm was specified for one individual, but we prefer to use 4 and to clone the best for each generation. Let us be more formal.

3.5 Matching problem

We specify a general problem that will be solved by Non-dissipative Gradualism here and by Dissipative Gradualism in the next section.

Matching problem specification: for random binary strings of length 1, 2, 3, ... make Non-dissipative Evolution to match each one of them and output the cost of the solution which is given by

cost = size of the population $\times$ *number of generations.*

The cost must be given as a function in the length of the input that is equal to the length of used binary strings, the same for all. Make a regression to find the general cost.

4 ***Exercise.*** *To estimate the cost of solving the Matching Problem by Non-dissipative Gradualism run the program* `NonDissptveGrad.html` *and report your conclusions.* *Answer*

5 ***Exercise.*** *The first graphic presented by the program* `NonDissptveGrad.html` *suggests that the cost of matching a password has a square root dependence on* $H =$ *password length. That is why a regression of the form* $y = aH^r$ *with* $0 < r < 1$ *was pursued and shown in the second graphic. Assess the proposed dependency.* *Answer*

Note. To test the root dependency, we recur to a logarithmic transformation:

$cost = y = aH^r$
If we take logarithm, we get:
$log(cost) = log(y) = log(aH^r) = log(a) + rLog(H)$.
So, if we rename
$w = log(y)$
$b = log(a)$
$x = log(H)$
we get
$w = b + rx$

That is why we make the linear regression of the logarithm of the cost over the logarithm of the password length. To restore the root expression, we use the exponential transform:

$y = exp(w) = exp(b+rx) = exp(log(a) + rlog(H))$
$= exp(log(a))exp(rlog(H)) = exp(log(a))exp(log(H^r)) = aH^r$

6 ***Exercise.*** *The presented algorithm is extremely fast. Is that impression a false illusion created by defective programming? Check the program by setting to true the various printing flags inside the code, one at a time, and choose low values of password length.*

7 ***Concourse.*** *Find the true dependency of the cost over the password length and support it graphically and mathematically. The root dependency is already out. Our proposal follows:*

Since we are not satisfied with proposing a root dependency of the cost of matching a password over the password length, we tried a logarithmic dependency which graphically seems to be well suited. To explain where it comes from, we propose the following reasoning that is valid for one individual.

The task is to match by Non-dissipative Gradualism a binary string of length H. There is only one individual, a string of the same length, that is transformed by Evolution. Set mutation per char per generation to 1 and turn off recombination. Then we must observe that in the initial setting at random, half of the sites will be guessed. Since we are in Non-dissipative Gradualism, correct sites get frozen. In the second generation, half of the half will be added to guessed sites while a quarter is left unsolved. We get in general:

First generation at random : matched fraction = $\frac{1}{2}$, Unmatched fraction = $\frac{1}{2}$.
Second generation : matched fraction = $\frac{1}{2}+\frac{1}{4}$, unmatched fraction = $\frac{1}{4}=\frac{1}{2^2}$.
Third generation : matched fraction = $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}$, unmatched fraction = $\frac{1}{8}=\frac{1}{2^3}$.
For generation i: matched fraction: $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+...+\frac{1}{2^i}$ Unmatched fraction $\frac{1}{2^i}$

Now, a generation n will arrive when only one site or bit from H is left to be resolved. This happens when

$H\frac{1}{2^n}=1$ or
$H=2^n$ or
$n=log_2(H)$

Hence, for a large population, one with 4 individuals suffices, the lacked bit will be added in the ensuing generation. So, the program will finish at generation $n=log_2(H)+1$. The predicted logarithmic dependence was verified graphically in program `NonDissptveGradLog.html`: for a population of 4 individuals, the dependency was $cost=4.1log_2(H)+0.4$, which looks satisfactory.

Let us notice that the log function is convex so, Non-dissipative Gradualism is the more efficient the larger is the password to be matched. Actually, it is also extremely cheap: it is sublinear, which means that for every cost function of the form $l=l(H)=aH+b$, that is for every a and b, there exists a c such that for $H>c$ the cost of Non-dissipative Gradualism is lesser, $cost(H)<l(H)$. An example of a linear function is that of writing a document that costs the same amount a for every letter. So the cost is of the form $l=aH+b$ where b is the fixed cost, say, to pay the right to use electricity.

8 ***Challenge.*** *Add the statistical significance up to the desired precision to all programs and their results.*

To summarize, we agree with a log dependency of the cost over H, the length of the input. We extrapolate that result to all values of H. Thanks to our mathematical work, we feel confident in our extrapolation, and we conclude that the dream of Darwin of Evolution as a killing complexity machinery has been realized in a variant of the Hangman game. Does this have something to do with this world?

3.6 Application

Non-dissipative gradualism is so fast that one wonders whether it is somewhere implemented in this world. Let us propose it as a solution to the terrible problem of why children so fast learn to speak. Chomsky proposed that human beings have a universal grammar that is wired in their brain's neural connections (Dubuc [4] 2000?). But non-dissipative gradualism might do the job. The key is that children have an incredible memory and their moms continuously give feedback to them. The net result is an implementation of the Hangman hint that we just studied: things are rapidly single out and learned forever. And this can produce astonishing results. This problem is a hot topic of Science (Yang [12] 2004).

3.7 Conclusion

We have shown that there exists at least one model where the dream of Darwin comes true and Evolution is a killer of complexity: it is Non-dissipative Gradualism. In it, mutation is at random and is a source of creativity, but once a site is guessed, it gets frozen, shielded from mutation. So, Evolution adds to perfection continuously and without setbacks.

4 DISSIPATIVE GRADUALISM

We have admired in the last section the striking possibilities of non-dissipative Gradualism, whose salient characteristic is that once a site is correct, it gets frozen and shielded from mutation. We consider that the dreams of Darwin are faithfully realized with this type of gradualism because Evolution is turned into a magic complexity killer. Our task now is to compare it with dissipative gradualism, in which nothing is shielded from mutation and so, achievements might be dissipated by mutation. Example:

```
101010 target string
110101 string with one matching site. Mutation produces:
010101 recoil to no matching.
```

We hurry to claim that **if gradualism is somewhere applicable to Natural Evolution, then it must be dissipative.** The reason is that it is universally accepted that mutation is at random and impossible to be shielded. Such a tremendous belief can be traced back to de Vries around 1901, who built his authority upon a very intensive work over plants. Moreover, he taught us that the environment cannot guide the direction of mutation, which occurs in jumps. In that way, he freed Evolution from the ideas of Lamarck and opposed the gradualism of Darwin (Hall [5] 1935). The molecular mechanisms of Evolution are indeed rich and complex and were not known by 1900 so, de Vries used the word mutation as a synonym of change of genetic effects that might be due to DNA mutation, recombination, or chromosome rearrangement.

Let us now specify our algorithm for simulating Dissipative Gradualism.

4.1 Evolution everywhere

Darwin proposes in 1859 the first scientific version of ET. The Synthetic Theory around 1930 blended his ideas with the notion of gene that was the heritage of Mendel. In this new version, Evolution is just the rising and lowering of gene frequencies. Later, in the 1950-60-70's, engineers worked out the Genetic Algorithm, which was a simulation of Evolution on computers (Holland [6] 1992). Formally:

The general Genetic Algorithm (GA), the credo of Dissipative Gradualism:

1. Declare a purpose, a target, a function to be optimized.
2. Use randomness to assemble a population of some initial solutions encoded in strings that receive the name of chromosomes.
3. Fine-tune solutions by iteration of:
   - Reproduction: solutions are cloned to form a new population. The probability of cloning a solution is proportional to its fitness or functional quality. In reality, there is too much freedom in the form that reproduction can be defined.
   - Random mutation: some chars are changed. No shielding. Everything can be mutated, dissipated.
   - Random recombination: part of a solution is concatenated to part of another solution to generate a new one.

One might consider that this was a curious work that might count as one more verification of the TE. Not that simple. By looking at a GA, one sees concepts that one uses every day. For instance:

To write a paragraph, we make many changes before we declare ourselves satisfied. A change represents a mutation. And to write a good paragraph, we combine parts of different paragraphs from possible different sources to form a new one. This operation is just a recombination. We suppose that we are experienced and very intelligent so, we can assess the quality of each piece of writing. Or, we can select the best of various options and forward it for more work. Notice that we gather rather small progress to achieve great things. This is precisely Gradualism.

To pass from writing paragraphs to biology, our selection procedure is replaced by automatic preferential reproduction and survival of those that do it better. And, more importantly, our intelligence is replaced by blind mutation + recombination.

Adding up altogether, we find :

Evolution Everywhere. The ingredients of the ET are mutation, recombination, reproduction with inheritance, selection, and gradualism. Hence, the ET predicts that the improvement of the selected function must be achieved in whatever environment one can imagine with these five ingredients.

Top journals show that GA's and Evolution Everywhere continue to provide today enlightenment and outstanding solutions to important problems.

Let us now make an important warning: Evolution is the result of a cooperative work of various factors.

4.2 Random mutation alone is just noise

Mutation works in all directions no matter how poisoning the result could be. Is mutation alone useful? Let us listen to an ancient diagnosis.

The complaint of Homer: nothing can be expected from random mutation because it is worse than Penelope: during three years she partially destroyed during the night what she weaved during the day. So, by the next morning, its shroud was rather incomplete. But if destruction is total, no progress is expected at all.

9 ***Concourse.*** *Put in equations the complaint of Homer. Equations must be artwork that combines simplicity with strength and predictive power. Our proposal is the following:*

Our task is to match a password of length H with strings of the same length. Let us pay attention to the fittest chromosome. Suppose that at a given instant of time t there are M_t sites that match the password. There are $H - M_t$ sites that do not match. Let us turn mutation on. The mutation rate is μ. This means that to pass to the next generation the number of sites that are touched by mutation is μM_t. When a site is touched, it is replaced by a random bit. Thus, half of them, $\frac{1}{2}\mu M_t$ will match the password. On the other hand, the $M_t - \mu M_t$ sites that are not touched continue to be correctly defined. At the same time, of the $H - M_t$ sites that are not correct, a fraction $\mu(H - M_t)$ will be touched. The half of them, $\frac{1}{2}\mu(H - M_t)$, will be correct, the other not. Adding all sites that match, we get:

$$
\begin{aligned}
&M_{t+1} = \tfrac{1}{2}\mu M_t + M_t - \mu M_t + \tfrac{1}{2}\mu(H - M_t)\\
&M_{t+1} = \tfrac{1}{2}\mu M_t + M_t - \mu M_t + \tfrac{1}{2}\mu H - \tfrac{1}{2}\mu M_t\\
&M_{t+1} = M_t - \mu M_t + \tfrac{1}{2}\mu H\\
&M_{t+1} = M_t + \mu(\tfrac{1}{2}H - M_t)\\
&M_{t+1} - M_t = \mu(\tfrac{1}{2}H - M_t)
\end{aligned}
$$

This means that the number of matched sites will increase when $\frac{1}{2}H - M_t > 0$ i.e. when M_t is below the half of the length of the password. Moreover, if by some reason M_t is greater, mutation will persecute matching sites until their number falls below $\frac{1}{2}H$. We see that when mutation works alone, mediocrity is the status quo. Can we escape somehow from this hell? Yes, we can. All we need is someone that offers us a hand.

The creativity principle. Mutation alone is nothing. But mutation becomes an invaluable source of creativity if someone can appreciate its findings. That someone is called selection. In Biology, selection does not exist, but it is a name for the automatic preferential reproduction of some individuals in the struggle for life.

These are called fittest and have DNA instructions that favor some aspect that help in surviving, say, they digest faster the lactic acid, which is a byproduct of metabolism and so, they do not get intoxicated under heavy duty.

Let us now use random mutation + selection to have Dissipative Gradualism to solve the password problem.

4.3 A Gedankenexperiment

The task is to match by Dissipative Gradualism a binary string of length H by individuals that are strings of the same length. Mutation is at random, knows nothing about good or bad effects on function, and selection is dictatorial, i.e., the fittest is reproduced and nothing else. Concretely:

The Dictatorial Algorithm: after each round of random mutation, choose the best and fill the world in it.

What will produce the recurrence of this procedure? When thinking about this, my head ran a simulation which promised to render Dissipative Gradualism into an almighty procedure to solve problems. It seemed so impressive that I decided to transcribe it accurately to examine what happened. This is what resulted:

Set mutation per char per generation to 1 and turn off recombination. Then we must observe that in the initial setting at random, half of the sites will be guessed in every individual.

Initial setting at random : matched fraction = $\frac{1}{2}$, Unmatched fraction = $\frac{1}{2}$.

Because selection is dictatorial, the new population consists entirely of clones of the best one, the dictator. So, the half of sites in every string is correct. Now, we apply random mutation. If the population is sufficiently large, in some individuals the matched sites would not be touched by mutation while all those unmatched sites will be touched. All this by mere randomness. Hence and about those individuals, half of the untouched sites, one-quarter of the total number of sites, will be flipped by mutation in the first generation to the correct value. So, half of the half of sites will be added to the matched fraction, while a quarter is left unsolved. We get:

Second generation : matched fraction = $\frac{1}{2}+\frac{1}{4}$, unmatched fraction = $\frac{1}{4}=\frac{1}{2^2}$.

Third generation : matched fraction = $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}$, unmatched fraction = $\frac{1}{8}=\frac{1}{2^3}$. For generation i: matched fraction $=\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+...+\frac{1}{2^i}$, unmatched fraction $\frac{1}{2^i}$

Now, a generation n will arrive when only one site or bit from H is left to be resolved. This happens when

$H\frac{1}{2^n}=1$ or
$H=2^n$ or
$n=log_2(H)$

Hence, for a large population, the lacked bit will be added in the ensuing generation. So, the task will be accomplished at generation $n=log_2(H)+1$.

The aforementioned description is not valid for the complete population but just for the fittest. We have proved a result that reads:

10 ***Theorem.*** *Dissipative Gradualism as implemented by the Dictatorial algorithm is a statistical deformation of Nondissipative Gradualism and is as fast as the last one if only enough resources are provided. In that case, this new Algorithm converges to a solution in a number of generations that is logarithmic in the length of the input H.*

11 ***Criticism.*** *The Theorem is mere vanity, it is as a useless lamp: if we have enough resources, randomness produces the perfect solution at once in the initial population.*

Let us look for another path, one simple, direct.

4.4 The cost of Dissipative Gradualism

Randomness and Evolution are both almighty in a world of unbounded resources. The world we live in is not like that. Here everything costs a lot. How large is the cost of Dissipative Gradualism to guess a password?

We have seen that just as predicted by Homer, random mutation alone working in a population of isolated individuals is a stagnating force that leads to the Hell of Mediocrity. But **if the ideas of mutation are appreciated by someone, it immediately is converted into a source of creativity to attack problems.** But this has a cost because mutation is an abstraction that is not seen. What one sees are mutants, and rare mutants need huge population numbers over many generations to appear. Our problem is estimating such numbers. Our first question is: how are the dynamics of the matching proportion, the proportion of sites that match?

12 ***Exercise.*** *Play with program `Dictator.html` that implements the Dictatorial Algorithm and shows the dynamics of the matching proportion. Extract your conclusions. Answer*

13 ***Concourse.*** *Make sense of the results of the simulation in program `Dictator.html`. Our proposal follows, step one of two:*

Let us calculate the case when by mere randomness all touched sites by mutation are converted to the right value. Hence, to be touched by mutation is to get correct. Let M_t be the number of matched sites in the Dictator at generation t. To pass to the next generation, the quantity of sites that are touched by mutation is μM_t. When a site is touched, it is replaced by a matching bit. On the other hand, the $M_t - \mu M_t$ sites that are not touched continue to be correctly defined. At the same time, of the $H - M_t$ sites that are not correct, a fraction $\mu(H - M_t)$ will be touched. In the considered case, all of them will be correct. Adding all sites that match, we get:

$$M_{t+1} = \mu M_t + (M_t - \mu M_t) + \mu(H - M_t)$$
$$M_{t+1} = \mu M_t + M_t - \mu M_t + \mu H - \mu M_t$$
$$M_{t+1} = M_t - \mu M_t + \mu H$$

$$M_{t+1} = M_t + \mu(H - M_t)$$
$$M_{t+1} - M_t = \mu(H - M_t)$$

This means that the number of matched sites will increase when $H - M_t > 0$ i.e., always. Hence, progress is not only guaranteed, but we also can make sure that the perfect solution will be incessantly approached because the force of progress is proportional to the lacking task. Also, when the task is almost complete, to progress a bit would take a longer time. This implies that the graphic opens downwards at the infinite. Moreover, it also opens downwards everywhere because the described process is also very simple.

14 ***Exercise.*** *Find the differential equation for the evolution of M_t, solve it, and compare your results with the simulation.* Answer

15 ***An intriguing success.*** *We have worked out a crude caricature of the effect of the variability created by mutation in a population. Astonishingly as it could be, our treatment has reproduced the shoulder silhouette of the curve that represents the evolution of the proportion of matched sites under Dictatorial Selection.*

Now, we need a second step because the plateau of the shoulder is not 1 but something below.

16 ***Exercise.*** *In the simulations, the top of the shoulder decreases as the length of the password augments. Explain why.* Answer

Let M_t be the number of matched sites in the Dictator at generation t. To pass to the next generation the number of sites that are touched by mutation is μM_t. Of them, $s\mu M_t$ are replaced by a matching bit. On the other hand, the $M_t - \mu M_t$ sites that are not touched continue to be correctly defined. At the same time, of the $H - M_t$ sites that are not correct, a fraction $\mu(H - M_t)$ will be touched. Of them, $s\mu(H - M_t)$ will be correctly flipped. Adding all sites that match, we get:

$$M_{t+1} = s\mu M_t + (M_t - \mu M_t) + s\mu(H - M_t)$$
$$M_{t+1} = s\mu M_t + M_t - \mu M_t + s\mu H - s\mu M_t$$
$$M_{t+1} = M_t - \mu M_t + s\mu H$$
$$M_{t+1} = M_t + \mu(sH - M_t)$$
$$M_{t+1} - M_t = \mu(sH - M_t)$$

This means that the number of matched sites will increase when $sH - M_t > 0$ and will decrease on the contrary case. Or, Evolution is a stagnating force around sH, with $0.5 < s < 1$ in general. This explains why there could be lowered shoulders: mutation being at random is not king Midas but anyway produces correct flipping whose average in the fittest is depicted by the s proportion.

17 ***Challenge.*** *We know from the simulation that the larger is H, the lower is the shoulder and henceforth s. This is a qualitative, possibly subjective assessment. Find the relation within s and H, firstly descriptively and then mathematically.*

18 ***Challenge.*** *Observe that in the simulations, which include random mutation, fluctuations around the equilibrium value sH are larger for small password lengths than for long ones. Is this a general and correct trend? Prove your assertion.*

Let us compare now Evolution and randomness.

19 ***Exercise.*** *Show that randomness alone always reach a perfect solution although the cost to be paid is exponential in the length of the input H.* *Answer*

20 ***Intrigue.*** *Randomness alone always can achieve perfection although at an exponential cost. Always. By contrast, Evolution is a stagnating force around under-perfection that is the more retrograde the larger is the password length. Does this mean that perfection is forbidden for the Dissipative Gradualistic Evolution? And, if it is not, which is most costly among randomness and Evolution?*

21 ***Exercise.*** *To answer the intrigue, run the program* `DissptveGrad.html` *and extract your conclusion.* *Answer*

22 ***Discussion.*** *Before accepting the results of the program, you might prefer to check the code. Do that by activating the printing flags that are inside the code. Once at a time and for values of password length less than 8.*

23 ***Concourse.*** *Defend the idea that the cost is exponential. Our proposal follows.*

The program `DissptveGrad.html` presents a regression graphic that seems to fit an exponential function. In the studied range, that is unquestionable.

The problem is with the extrapolation to high values of password length, even to infinite. It happens that a graphic is no proof of exponential extrapolations. The reason is that an exponential dependence cannot be proved by a simulation because any finite set of points in the plane can also be fitted by a polynomial and every polynomial is in the long-range infinitely cheaper than an exponential cost. So, it is abusive to pretend that the dependence is exponential based on a graphic. But a succession of graphics might do it better because one sees that the exponential trend is stable. This is done by studying varying values of password length. In the case of stability, as it is found here, a polynomial fitting loses meaning because no polynomial can accompany an exponential over a long-range, rather a permanent growth of the leading exponential of the polynomial is expected.

Now we have a mess: on one hand, the extrapolated cost to high values of password length might be polynomial. On the other hand, it might be exponential as the regression suggests. And in the air, we also might have that the function cost is ill-defined because Evolution gets frustrated and is unable to reach perfection.

To rule out the third option, we offer our faith in the power of Evolution: it can reach perfection indeed. The reason is that Evolution does not kill the creativity of wild randomness. In effect: Mutation in Evolution is the very same mutation in isolation. Moreover, recombination in Evolution is an operation that produces great jumps in string space. Hence, we do not believe that the creativity of randomness in Evolution is diminished in comparison with its work in isolation. So, the effect of randomness on the retrograde background of Evolution is not diminished: it remains alive.

In second place,

The cost of the binary matching problem by Gradual Dissipative Evolution cannot be less than exponential in the length of the input:

In the beginning, you must just match some bits, a task that is quite easy. But as you increase the level of matching, you gain information that you must keep from been destroyed by mutation. The larger is the gained information, the wider is the field of the destructive action of mutation. To shield your information from mutation you must make many copies so that some of them receive by randomness the correct direction of mutation. So, gained information functions as a large security password with all-else-nothing matching. Why?

Since fitness is not assigned to specific chars but only to organisms, you have no idea if a particular change is good or bad. Then you must try all possible assignments so that the fitness function could choose the fittest. And this has an exponential cost.

24 ***Exercise.*** *Prove that there are infinitely many forms of being mediocre and under-perfect. Make your predictions about the fossil record.* *Answer*

4.5 Practical problems

We have stated that to use Evolution to solve problems might be extremely costly. **How good is Evolution in comparison with, say, the worst case searching strategy?**

25 ***Exercise.*** *Run program* `DissptveGradVsRand.html` *to compare in one place the performance of Evolution with that of randomness and with the worse case searching. The cost of this last method is* 2^n *because that is the number of options to test in the worst case to find a binary string* n *bits long.* *Answer*

Another fold of complexity is that **expensive problems in Industry and Science must not be solved exactly but only approximately.**

26 ***Exercise.*** *Run program* `DissptveGradCostVsR.html` *to study the cost of matching a password against* r*, the degree of approximation of the solution once a given password length is chosen.* *Answer*

27 ***Challenge.*** *Prove that the dependency of the cost over r is not exponential but supra-exponential. Find the dependency explicitly.*

28 ***Exercise.*** *Use the program* `DissptveGradCostVsR051.html` *to show that the cost of matching a password when the approximation degree r equals* 0.51 *is exponential in the password length. Find the exponent. This explains why we are enslaved to mediocrity: augmenting quality imposes an overburden of resources. Or equivalently, research for high quality is exclusive of people with a very high sense of honor, rich enterprises, and powerful countries.* Answer

29 ***Challenge.*** *Prove that the exponential dependency found in Dissipative Gradualism is valid for every setting of the values of the parameters, population size, mutation, and recombination rates.*

30 ***Challenge.*** *Evolution can be implemented in various ways. Say, reproduction can be dictatorial. Or it can be righteous when the probability of reproduction of an individual is proportional to its fitness. Prove that if one implementation of Evolution needs an exponential cost to solve a problem, so do all others. This means that for Science, Evolution is too wasteful to be of any use. But for engineering, the differences among implementations might be abysmal and so, specific families of problems must be assigned to specific implementations to minimize costs.*

The following concourse sheds light on the problem of the necessary diversity of implementations of Evolution.

31 ***Concourse.*** *The way we have implemented Evolution is useless in the case when one must deal with strings of various lengths and with Evolution that affects the lengths of strings. Devise the best mechanism to attack those problems. Our proposal is to work with duplication, deletion and trimming as in program* `DissptveGrad1010.html`.

32 ***Challenge.*** *Prove that if a problem has an exponential cost for Evolution, then it has an exponential cost for whatever other method. If this is proved, complexity can be called objective.*

4.6 The meaning of exponential cost

In a simulation one feels that one is dealing with a problem with an exponential cost when the first instances of the problem are immediately solved, then some slowness began to appear, and next all of a sudden one stumbles against an interminable delay without no reported solution. For the binary matching problem, the burden of complexity is too heavy for a password length of 25.

To perceive the implication of an exponential cost, let us consider the simplest exponential function:

$y = e^x$

Taking derivative:

$\frac{dy}{dx} = e^x$
$dy = e^x dx$

if we pose $dx = 1$, we get:

$dy = e^x$

that reads: if we increment the length in one, moving from x to $x+1$, the increment of the cost is e^x. So, the greater is x, the increment in the cost y will be exponentially greater, and very soon the resources in the whole universe will get insufficient. We can see this if we try to fabricate a number greater than 10^{1000} using the fundamental constants of nature. To try that out, let us consider that

- The minimum measure of time is an instanton which is given by the Planck time, which is 5.4×10^{-44} seconds.
- The minimum distance in space is the Planck length, 1.6×10^{-35} meters (Wolfe [14] 2005).
- The universe has 13.77 billion years (Letzter [9] 2020).
- The diameter of the universe is 93 billion light-years (Baraniuk [1] 2016).

So, we have:

Minimum time length:
5×10^{-44} seconds which gives
$\frac{1}{5 \times 10^{-44}} = 2 \times 10^{43}$ instantons in a second.

Age of the universe: 14 billion years or
14×10^9 years or
$14 \times 10^9 \times 365 \times 24 \times 60 \times 60 = 5 \times 10^{17}$ seconds.
Hence, the universe has existed during
$2 \times 10^{43} \times 5 \times 10^{17} = 10^{61}$ instantons.

Let us calculate now the number of elementary space three-dimensional cells that are contained in the universe:

A chorismion is the Planck length, 1×10^{-35} meters. So, a meter has 10^{35} chorismions, minimal units of length. Hence in a cubic meter, there is a place for 10^{105} Planck cells. If we take the diameter of the universe as 100 billion light-years or 100×10^9 light-years or

$100 \times 10^9 \times 365 \times 24 \times 60 \times 60 \times 300 \times 10^3 \times 10^3 = 10^{27}$ meters, the volume of the Universe is
$(10^{27})^3 = 10^{81}$ cubic meters. So, the universe has place for
$10^{105} \times 10^{81} = 10^{200}$ elementary cells.

If we multiply the number of instantons by the number of cells, we get an estimation of the upper bound of elementary processes that might have occurred in the universe along its whole life:

$$10^{61} \times 10^{200} = 10^{300}$$

This number can be understood as the capital that the Universe has to do things. Let us see now how much it costs to guess our DNA.

According to our simulations, the cost of matching a binary password x bits long is roughly $y = e^x = 10^{0.5x}$.

Let us recall now that the human genome has 3 billion bases. Since there are 4 bases, each base occupies 2 bits. So, the human genome can be rewritten in a binary string of 6 billion bits. So, the associated cost to match them by gradualism is of the order of

$$\text{Cost} = y = 10^{0.5 \times 6 \times 1000000000} = 10^{3 \times 1000000000}$$

We must **compare now the capital with the cost of guessing our DNA**:

33 ***Exercise.*** *Assess the following accusation: We see that the Universe was not built to give life from itself: there is a chronic and lethal deficiency of resources to pass beyond mediocrity in complex problems, such as life is, even if the whole universe is taken into account. Hence, Evolution is not and cannot be the explanation of the existence of any genome.* Answer

34 ***Exercise.*** *Use our results to concoct a robust falsification of the Gradualistic ET or show that it does not exist.* Answer

35 ***Graduation.*** *Compress into a slogan the ideology of this work that is the very same of everyone that struggles in this life for doing something good. Example: The slogan of the ET is:* NOTHING IN BIOLOGY MAKES SENSE IF NOT IN THE LIGHT OF EVOLUTION. *It was a marvelous invention by the Ukrainian Theodosius Dobzhansky ([3] 1973), who emigrated to USA in 1927. He represents those that think that the belief in God and in the ET are compatible.*

5 CONCLUSION

36 ***Challenge.*** *Formulate clearly and succinctly the main results and their biological implications. Consider the fossil record as well as the anatomy and physiology of present species and individuals, including yourself.*

Answers

Exercise 4, page 10. The program is very fast. The more lengthy a task is, the more efficient is the non-dissipative gradualism.

Exercise 5, page 10. The regression of the form $y = aH^r$ fails because the exponent changes according to the considered range: for the range $1...100$, $r = 0.5$. But for for the range $1...5000$, $r = 0.2$.

Exercise 12, page 16. Short passwords, lengths less than 10, are guessed almost immediately. As length is increased a bit, the dynamics obey a shoulder tendency in which a rapid advance happens at the beginning followed by a very slow convergence to the maximal value which is 1, i.e., perfection. For large lengths, length above 25, the shoulder is also observed but seems to be frustrated at some value within 0.5 at 1.

Exercise 14, page 17. The equation

$$M_{t+1} - M_t = \mu(H - M_t)$$

can be read as follows if we consider that the unit of time is Δt:

$$\Delta M = (M_{t+\Delta t} - M_t) = \mu(H - M_t)\Delta t \ \frac{\Delta M}{\Delta t} = \mu(H - M_t)$$

This equation is valid for finite intervals of time. We can extend it to infinitesimal times as a differential equation:

$$\frac{dM}{dt} = \mu(H - M) \ \frac{dM}{dt} + \mu M = \mu H$$

The right side of this equation says that we are dealing with an exponential function ae^{kt}, while the left side that we must add a constant c. So, we postulate a solution of the form:

$$M = ae^{kt} + c$$

After replacing that solution into the differential equation, we get:

$$\frac{d(ae^{kt}+c)}{dt} + \mu(ae^{kt} + c) = \mu H \ ake^{kt} + \mu ae^{kt} + \mu c = \mu H$$

These equations are among functions. So, the exponential on the left side must be equated to the exponential on the right side, and the equivalent with constants. We get:

$$ake^{kt} + \mu ae^{kt} = 0$$

Hence,

$ak + \mu a = 0$ or $a(k + \mu) = 0$. Since a cannot be null because there would be no process,

$k + \mu = 0$ or

$k = -\mu$.

On the other hand, equating constants in both sides of the original equation:

$\mu c = \mu H$

or

$c = H$.

Thus,

$M = ae^{kt} + c$ becomes

$M = ae^{-\mu t} + H = H + ae^{-\mu t}$

If we pose $M(0) = H/2$, as expected for a random guessing, we get:

$H/2 = H + a$

or

$a = -H/2$

And

$M = H - \frac{H}{2}e^{-\mu t}$ $M = H(1 - \frac{1}{2}e^{-\mu t})$

Hence, the dynamics of p, the proportion of guessed bits, is:

$p = \frac{M}{H} = (1 - \frac{1}{2}e^{-\mu t})$

This function starts at $1/2$ and grows steadily towards 1. It always opens downwards because the second derivative is always negative.

Exercise 16, page 17. The shoulder silhouette was derived assuming that every site touched by mutation is converted to the right value, as in the storytelling of king Midas. To explain why the shoulder gets down as complexity or password length grows, let us try the following Ansatz: Not every site touched by mutation gets correct but only a fraction s of them. So:

Exercise 19, page 18. The probability of matching any one site by randomness is $\frac{1}{2}$, so the probability to match n independent sites is $\frac{1}{2^n}$. Hence, the average cost of matching them all together is 2^n. It is exponential in n, the length of the input. But only in average.

Exercise 21, page 18. The program declares that the cost is exponential as for Randomness as for Evolution.

Exercise 24, page 19. Our programs create a population of binary strings that are generated at random and that evolve with operations that are inbuilt in randomness. And results are always the same: short strings are guessed instantaneously, but as the length increases, under-perfection becomes the norm. With length in the thousands, to lift off mediocrity should be exponentially costly. This means that our processes visit the whole space of possibilities and hence that all flavors of mediocrity and under-perfection are realized during very long times. Therefore, when fossil records are possible, these must be dominated by every sort of imperfections. By the same token, every sort of failures must abound in all newborns of all species.

Exercise 25, page 19. Worst case searching is more expensive than randomness that is more expensive than Evolution. Anyway, all methods have exponential cost:

```
WorstCase searching:
cost = 1e^(0.69x)
Randomness:
cost = 0.4e^(0.69x)
Evolution:
cost = 1e^(0.62x)
```

Exercise 26, page 19. For short sequences, lengths less than 15, there is no problem. When the length is a bit larger than 15 one can see that low quality is very cheap and that problems begin with $r = 0.9$. For length 50 troubles begin with $r = 0.8$. The program insinuates that the dependency of the cost over r is exponential. Nevertheless, curves does not fit an exponential but tend to overflow.

Exercise 28, page 20. We are considering an extremely low approximation degree. For low password length, random mutation would hide away the role of password length. So, to reveal any systematic effect of password length, we need to explore very long passwords. To this aim, we took passwords whose length is a multiple of 10000. We found that the dependency is exponential: $cost = e^{0.0002x}$. This means that $cost = 10^{1000} = e^{2303}$ is achieved when $0.0002x = 2303$, e.i., when $x = 12$ millions. In molecular biology, this length is tiny.

Exercise 33, page 22. The accusation is weak because Evolution is used every day to produce great things and because everything is possible for randomness alone.

Exercise 34, page 22. An incontestable falsification of the Gradualistic TE is based on the fact that it predicts a mandatory Evolution of Perfection. We can sustain it as follows: the cost to achieve perfection is exponential in the length of the binary password. Now, the derivative of an exponential is an exponential. This means that the cost of guessing a new bit is exponential and because the cost is proportional to the number of generations, this implies that each success is followed by stagnation whose duration is proportional to the number of previous steps. Hence, the Gradualistic TE predicts that the fossil record must be filled in mediocre and under-qualified witnesses of the Evolution of Perfection. But moreover, that testimony must be visible in our own body, anatomy, and physiology. So, just look at yourself and decide: Are you perfect? The very same result and analysis can be made by using the program `DissptveGradCostVsR.html` which might be reinforced with program `DissptveGradCostVsR051.html`.

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