

# “The evolutionary origin of complex features”

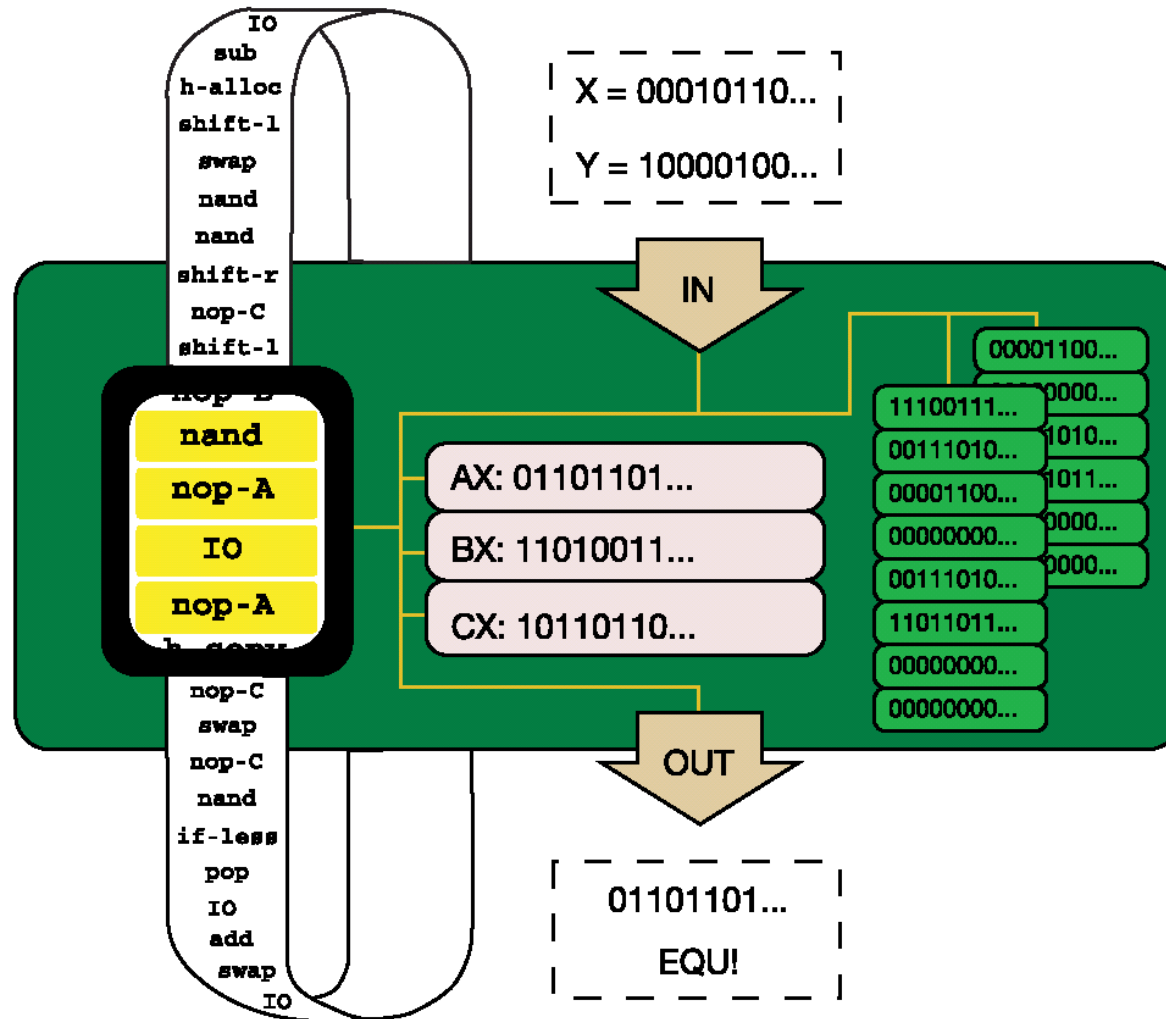
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# Simulating evolution



# Model features

- 26 instructions, only one logic function (NAND)
- Sequential processing, plus jumps
- Asexual reproduction
- Mutation only, no crossover
- Start with organisms that have copy ability, but no logic function ability
- Organisms get energy by doing multi-step logic functions

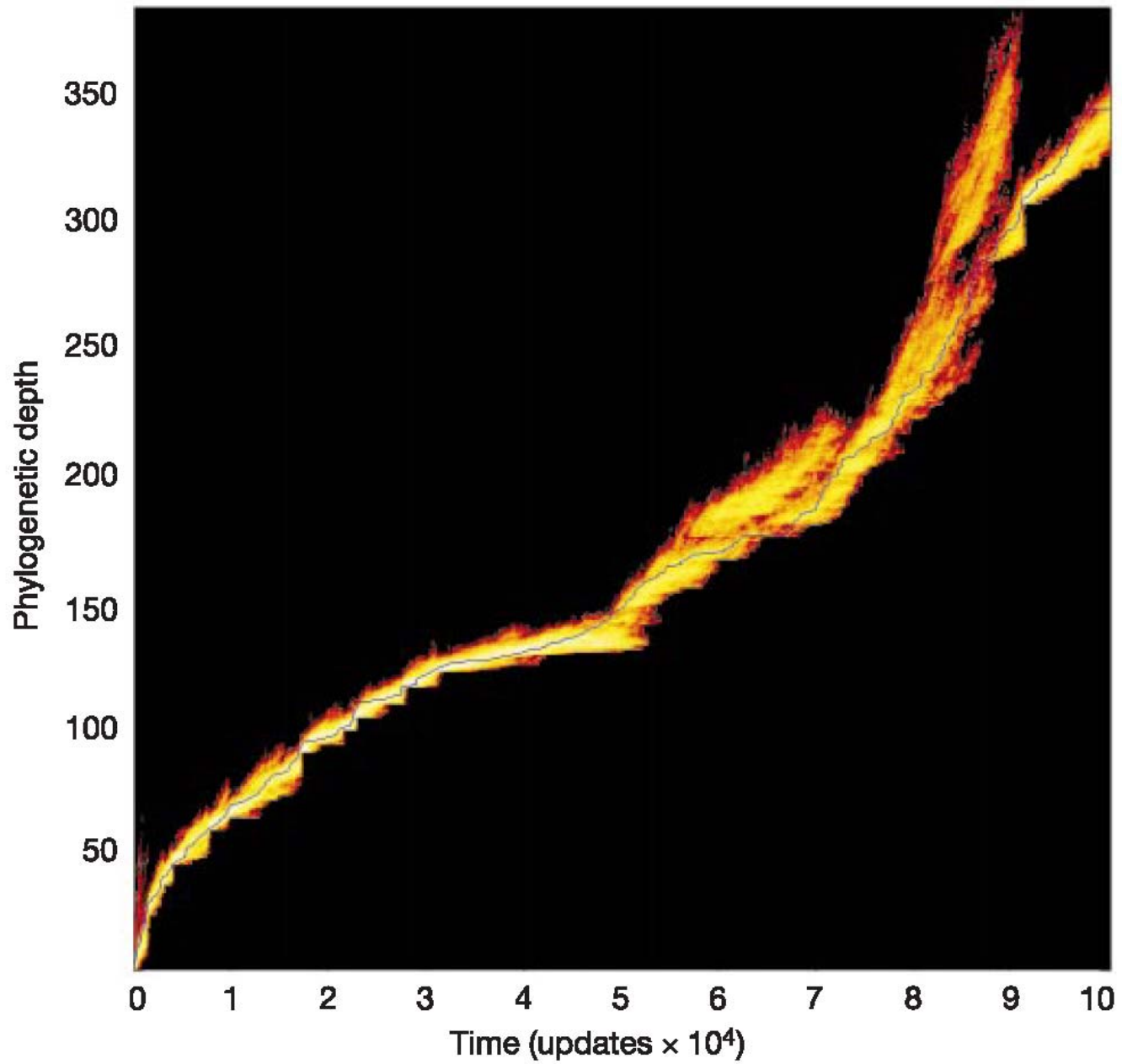
# Fitness rewards

Table 1 **Rewards for performing nine one- and two-input logic functions**

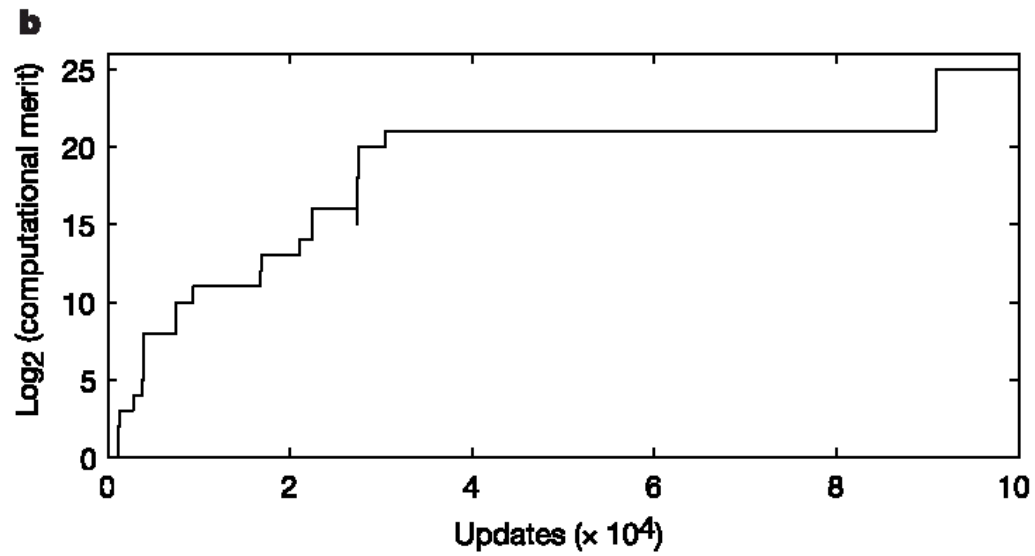
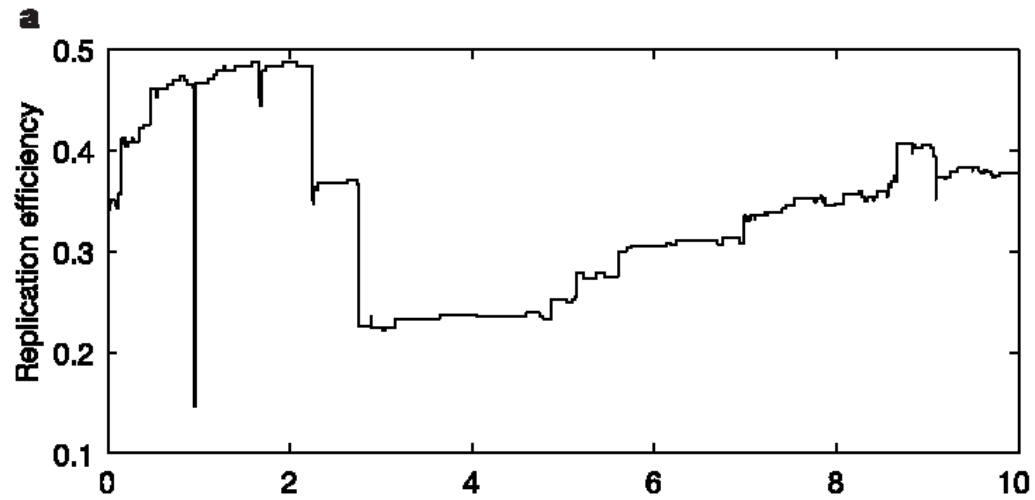
Function name	Logic operation	Computational merit
NOT	$\sim A; \sim B$	2
NAND	$\sim(A \text{ and } B)$	2
AND	A and B	4
OR_N	(A or $\sim B$ ); ( $\sim A$ or B)	4
OR	A or B	8
AND_N	(A and $\sim B$ ); ( $\sim A$ and B)	8
NOR	$\sim A$ and $\sim B$	16
XOR	(A and $\sim B$ ) or ( $\sim A$ and B)	16
EQU	(A and B) or ( $\sim A$ and $\sim B$ )	32

The symbol ' $\sim$ ' denotes negation. The reward for computational merit increases with  $2^n$ , where  $n$  is the minimum number of nand operations needed to perform the listed function. Symmetrical operations, shown separated by a semi-colon, are treated as the same function. No added benefit is obtained for performing any function multiple times. These functions include all one- and two-input logic operations except ECHO, which requires no nand operations and was not rewarded.

# Phylogenetic depth



# Fitness trajectories



Surprisingly, some mutations in the lineage of the eventual dominant genotype were deleterious (two even reduced fitness by  $>50\%$  temporarily)

Were these deleterious mutations essential or incidental? By replaying history, they were found to be essential!

# Functional-genomic array

Instruction	Repl.	NOT	NAND	AND	OR_M	OR	AND_N	NOR	XOR	EQU
1 r <i>h-alloc</i>	Red									
2 m <i>dec</i>						Red	Red	Red		Red
3 z <i>set-flow</i>	Red									
4 a <i>nop-A</i>	Red									
5 v <i>mov-head</i>	Red									
6 c <i>nop-C</i>	Red	Red			Red	Red	Red	Red		Red
7 g <i>push</i>										
8 m <i>dec</i>										
9 c <i>nop-C</i>							Red			
10 i <i>swap</i>										
11 q <i>IO</i>										Red
12 q <i>IO</i>										Red
13 p <i>nand</i>		Red								
14 t <i>h-copy</i>										Red
15 q <i>IO</i>		Red		Green		Red	Red	Red		Red
16 p <i>nand</i>				Green		Red	Red	Red		Red
17 q <i>IO</i>				Green		Red	Red	Red		Red
18 c <i>nop-C</i>						Red	Red	Red		Red
19 p <i>nand</i>						Red	Red	Red		Red
20 c <i>nop-C</i>				Green		Red	Red	Red		Red
21 t <i>h-copy</i>						Red	Red	Red		Red
22 l <i>inc</i>						Red		Red		Red
23 e <i>if-less</i>										Red

Chart is for first EQU organism.

Top row, red means can't do this function, green means can.

Inside chart, red means effect of NOP'ing that instruction.

Many interacting components for the complex functions—remove any one element, and the complex functions break.



# Building blocks

“Reward All Simpler Functions”:

46% found EQU

“Reward All But One Two Simpler Function”:

34% found EQU

“Reward None”:

0% found EQU

# Conclusions

- Incremental increased fitness for “steps” is essential for evolution of more complex features. For populations with no fitness for subfunctions, “...none of these populations evolved EQU...” and incremental increased fitness for building blocks is “...precisely what evolutionary theory requires...”
- Complex features depend on the delicate interaction of many elements. But they do occur!
- No *particular intermediate stage was essential*
- Evolution not a linear progression; it uses steps backward and sideways and makes unexpected use of past incidental creations

# Criticisms

This is necessarily a very crude model of real evolution (genotype to phenotype conversion is vastly simpler, reproduction is asexual, ...)

Can anything really be concluded from it?

Does the paper assume what it is trying to prove?  
(Authors address this question, and unsurprisingly, their answer is “no”.)

Intro

Caltech  
Fruit Fly guy  
this paper is unusual (for Nature) and exciting (to me!)

Pocket Watch

William Paley, *Natural Theology* (1802) (read quote)  
Influential even for Darwin (read quote)  
Dennett's "design stance"--as engineers, we *treat* humans as if they had been designed.  
    Why is this structure here? What is that chemical doing?  
Still a contentious issue: Darwin's Black Box (same argument at biochemical level), Behe, Dembski

Simulating evolution:

little programs  
genome  
competition  
performance on some task; competition for resources  
mutation, insertion, deletion  
replication/crossover  
is reproduction part of "system" or encoded in genome?  
SIP: single instruction processing unit, think of this as 'food'  
    get from 2 things, genome length and logical operands  
NAND is the only logical primitive in the language, but NAND is functionally complete  
mention "core wars"

Logic Table

work out truth tables  
human programmer implemented EQU program in 19 instructions (without replication)  
explain why logarithmic progression of fitness values: so that making the next step is worth more than all steps up to that point;  
    it is better to go ahead even if it means giving up progress made so far

Phylogenetic depth

what color means  
multiple mutations required  
talk about speciation

Functional-genomic array

Def: epistatic An interaction between nonallelic genes, especially an interaction in which one gene suppresses the expression of another.  
(Def: Pleiotropic The control by a single gene of several distinct and seemingly unrelated phenotypic effects.)

Conclusion

Criticism

mention iterated prisoner's dilemma?

In order to pass the B.A. examination, it was, also, necessary to get up Paley's Evidences of Christianity, and his Moral Philosophy. . . The logic of this book and as I may add of his Natural Theology gave me as much delight as did Euclid. The careful study of these works, without attempting to learn any part by rote, was the only part of the Academical Course which, as I then felt and as I still believe, was of the least use to me in the education of my mind. I did not at that time trouble myself about Paley's premises; and taking these on trust I was charmed and convinced of the long line of argumentation.

Charles Darwin. Autobiography

Paley wrote several books on philosophy and Christianity, which proved extremely influential. His 1794 book *A View of the Evidence of Christianity* was required reading at Cambridge University until the 20th century. His most influential contribution to biological thought, however, was his book *Natural Theology: or, Evidences of the Existence and Attributes of the Deity, Collected from the Appearances of Nature*, first published in 1802. In this book, Paley laid out a full exposition of natural theology, the belief that the nature of God could be understood by reference to His creation, the natural world. He introduced one of the most famous metaphors in the philosophy of science, the image of the watchmaker:

. . . when we come to inspect the watch, we perceive. . . that its several parts are framed and put together for a purpose, e.g. that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day; that if the different parts had been differently shaped from what they are, or placed after any other manner or in any other order than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use that is now served by it. . . the inference we think is inevitable, that the watch must have had a maker -- that there must have existed, at some time and at some place or other, an artificer or artificers who formed it for the purpose which we find it actually to answer, who comprehended its construction and designed its use.

Living organisms, Paley argued, are even more complicated than watches, "in a degree which exceeds all computation." How else to account for the often amazing adaptations of animals and plants? Only an intelligent Designer could have created them, just as only an intelligent watchmaker can make a watch:

The marks of design are too strong to be got over. Design must have had a designer. That designer must have been a person. That person is GOD.

And, as Paley went on to argue, if God had taken such care in designing even the most humble and insignificant organisms, how much more must God care for humanity!

The hinges in the wings of an earwig, and the joints of its antennae, are as highly wrought, as if the Creator had nothing else to finish. We see no signs of diminution of care by multiplicity of objects, or of distraction of thought by variety. We have no reason to fear, therefore, our being forgotten, or overlooked, or neglected. <http://www.ucmp.berkeley.edu/history/paley.html>

In crossing a heath, suppose I pitched my foot against a stone and were asked how the stone came to be there, I might possibly answer that for anything I knew to the contrary it had lain there forever; nor would it, perhaps, be very easy to show the absurdity of this answer. But suppose I had found a watch upon the ground, and it should be inquired how the watch happened to be in that place, I should hardly think of the answer which I had before given, that for anything I knew the watch might have always been there. (from *Skeptic*)