The Origin of Computable Numbers

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Turing and Darwin

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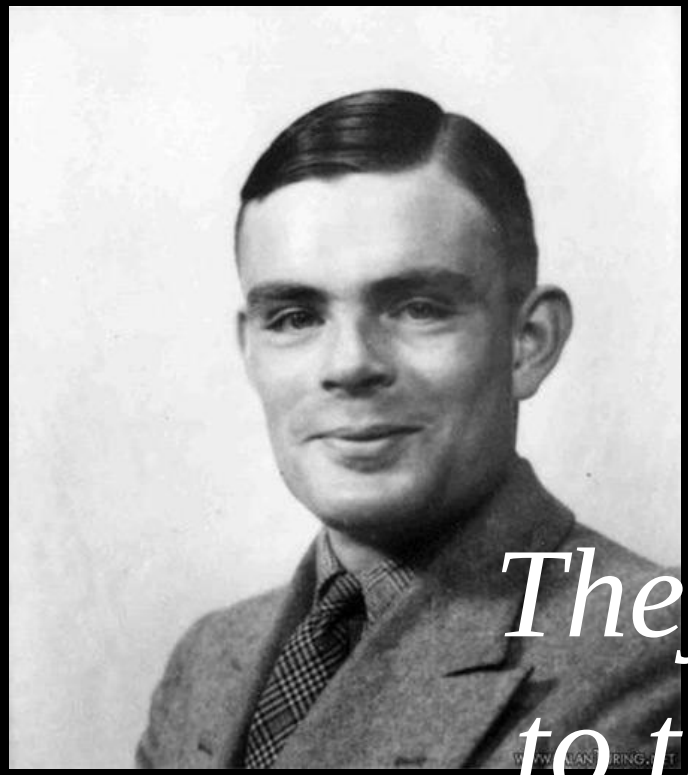
Turing and Darwin

What can they have in common?

Turing and Darwin

Turing and Darwin



They both came to the Americas for graduate work

Turing and Darwin

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Changed the world

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Changed the world
through a scientific work

Turing and Darwin

Changed the world
through a scientific work
that was singularly compelling

Turing and Darwin

Changed the world

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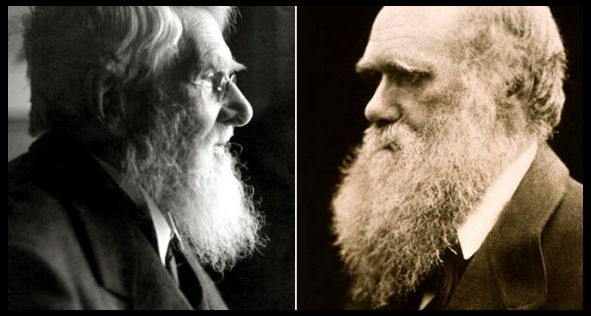
that was singularly compelling

and aware of its own greatness and place in history

Scooping



The Darwin-Wallace papers

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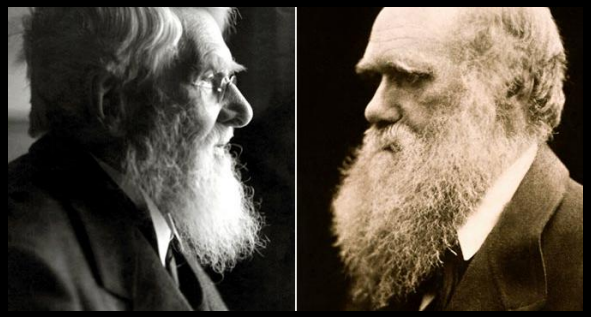

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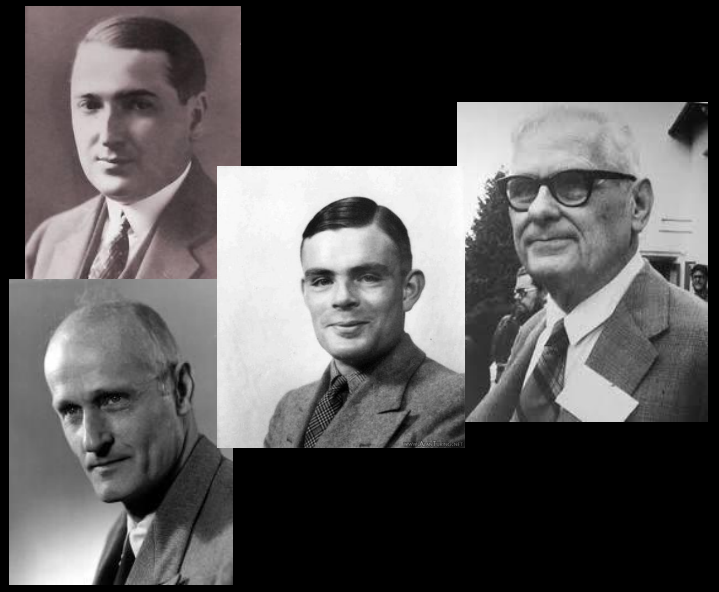

When it rained models of computation

They took their time…

- 28 years

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- 28 years

- 11 months

The revisions

- 1859, 1860, 1861, 1866, 1869, 1872

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Errata: Series 2, 43 (1937), pp 544–546

The contributions, in three words

- Natural selection
- Commonancestry

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- Natural selection
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- (Un)decidability
- Universality
- Entschei… *Wha?*

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Universality

- Vision or programming exercise?
- A minority opinion in the 1930s
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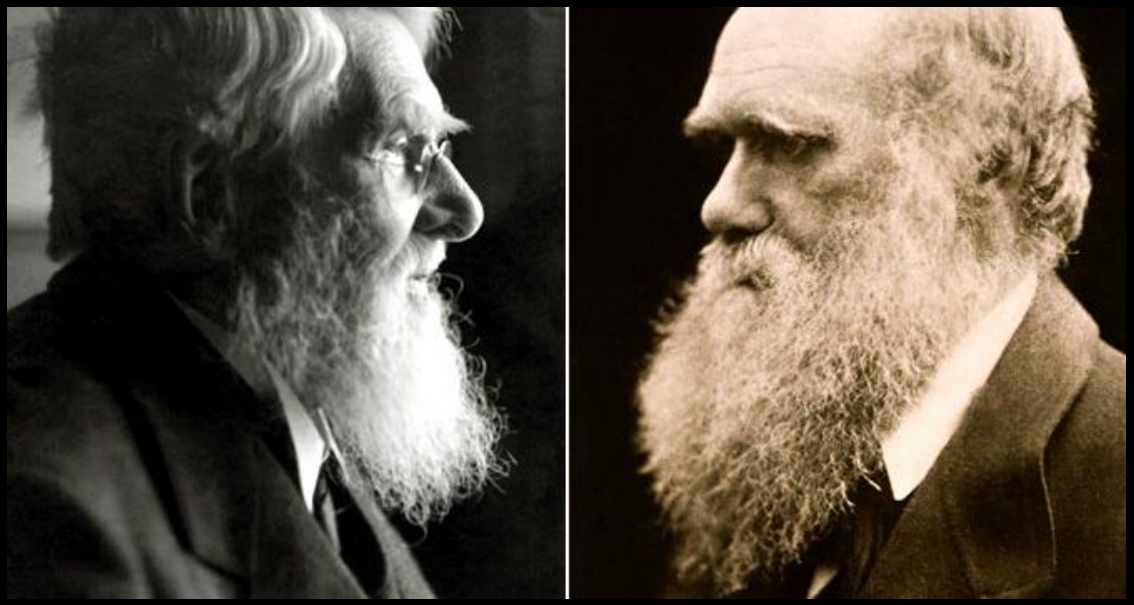
- Presaged software
- Brought us the Internet

Computational Thinking about Evolution

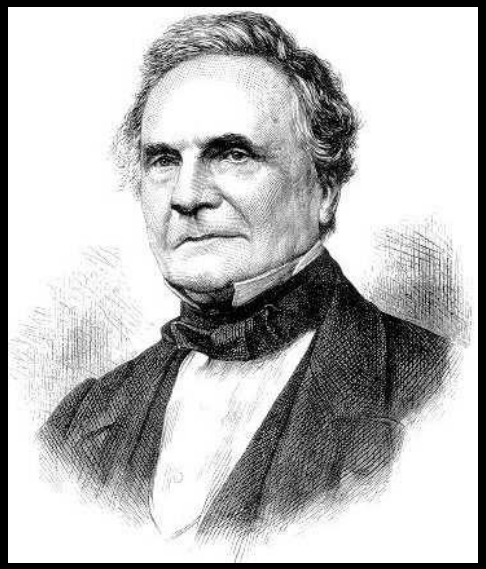
Exponential growth



The Darwin-Wallace papers

The computer's great-grandfather!

- Charles Babbage
  1830



[Paraphrased]

"God created not species, but the Algorithm for creating species"

Crypto against Lamarck

- A. Weismann, 1880

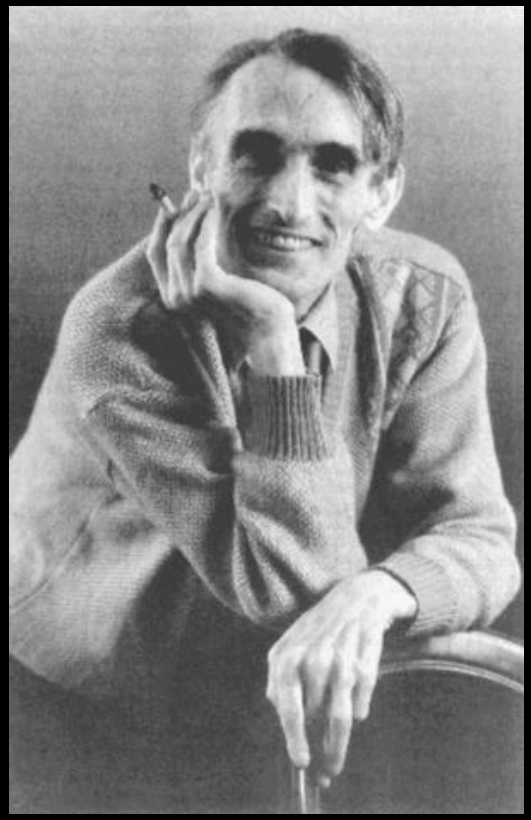
[Paraphrased]

"The mapping from genotype to phenotype is one-way"

Disbelieving Marco

"Our thesis is that Neo-Darwinism cannot explain the basic phaenomena of evolution on the basis of physico-chemistry"

Schutzenberger, 1966



Evolvability: Evolution as Learning

"How do you find a 3-billion
ng string in 3 billion years?"

L. G.Valiant

The mysterious case of evolution-inspired heuristics

?

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- Simulated annealing and other local search algorithms (inspired by asexual natural selection) often perform well

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- Simulated annealing and other local search algorithms (inspired by asexual natural selection) often perform well
- The genetic algorithms (inspired by natural selection under sex/recombination) do not
- In Nature, sex is successful and ubiquitous

?

?

But sex itself is a mystery in evolution

- Wastes half the genes
- Breaks down lucky gene combinations
- Genetic complexity of sex mechanisms, energy costs to the organism
- [Barton + Charlesworth, *Nature* 1998]

  "Why sex and recombination?"
- *"The queen of problems in evolution"*

The parallel mysteries

- Why is sex successful in Life but unsuccessful when coded in heuristics?
- Why is sex ubiquitous in Life despite its load?

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- Natural selection under ***asex*** optimizes fitness
- But under ***sex*** it favors ***mixability:***
- = The ability of alleles (gene variants) to perform well with a broad spectrum of other alleles

Explaining Mixability

- Fitness landscape of a 2-gene organism

Explaining Mixability (cont)

- Asex will select the largest numbers

3	2	4	5	4
1	0	0	7	2
2	1	0	4	3
1	8	1	3	2

Explaining Mixability (cont)

- But sex will select the rows and columns with the largest average*

3	2	4	5	4
1	0	0	7	2
2	1	0	4	3
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The Argument for Mixability

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3. A proof for weak selection [P. 2012]

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- PS: Lessons for genetic algorithms

Turing’s most cited paper:

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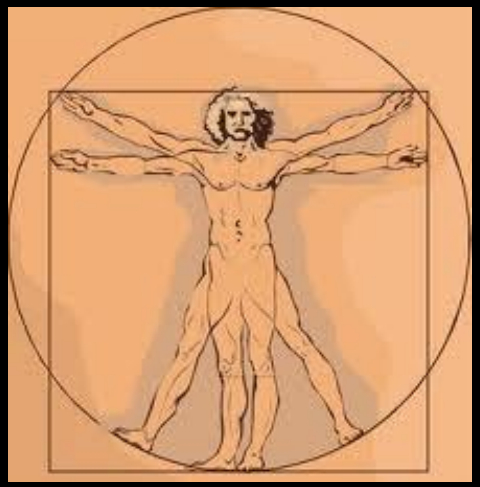
"The chemical basis of morphogenesis," 1952



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Reaction-diffusion model creates spatial stationary waves

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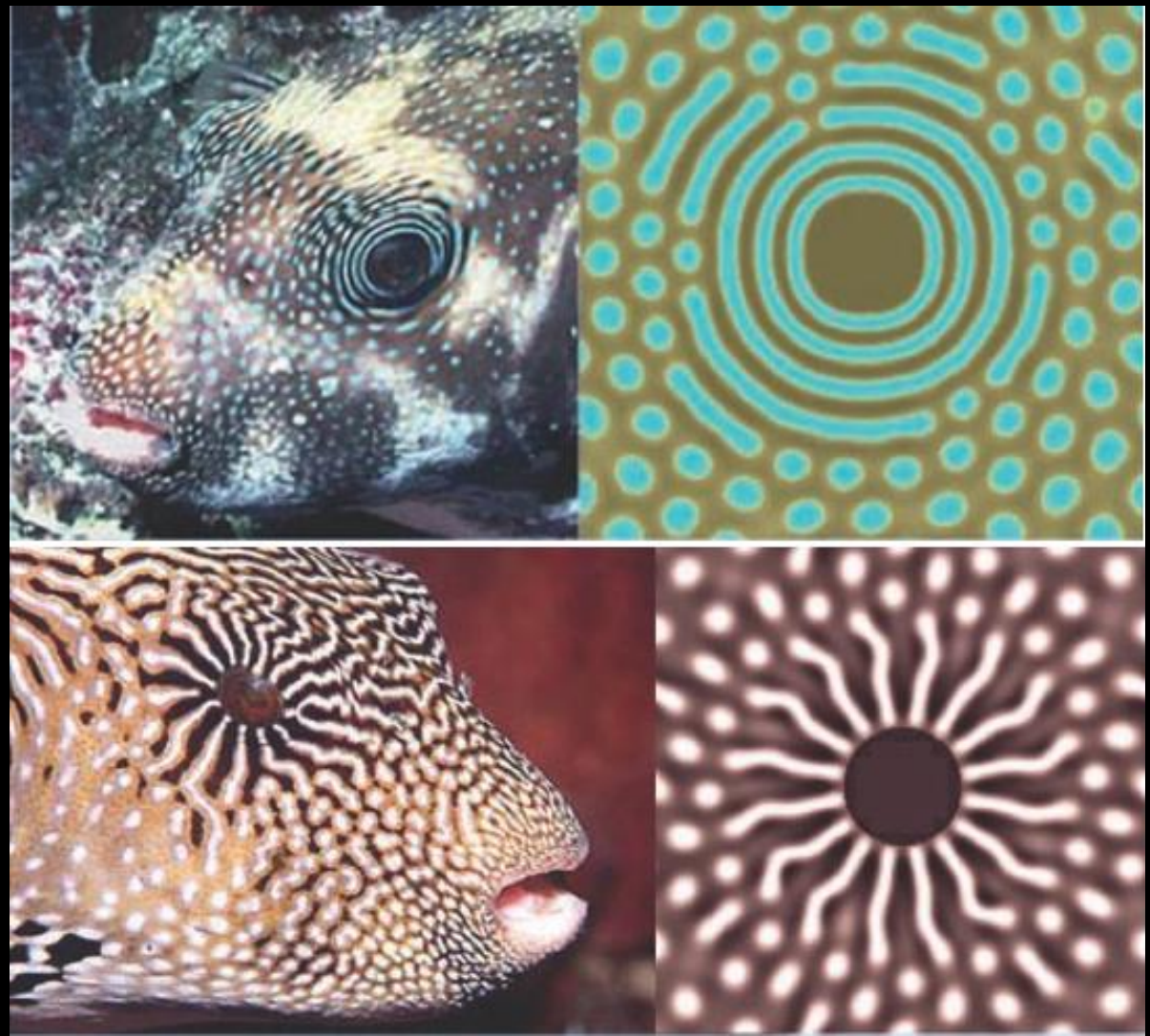

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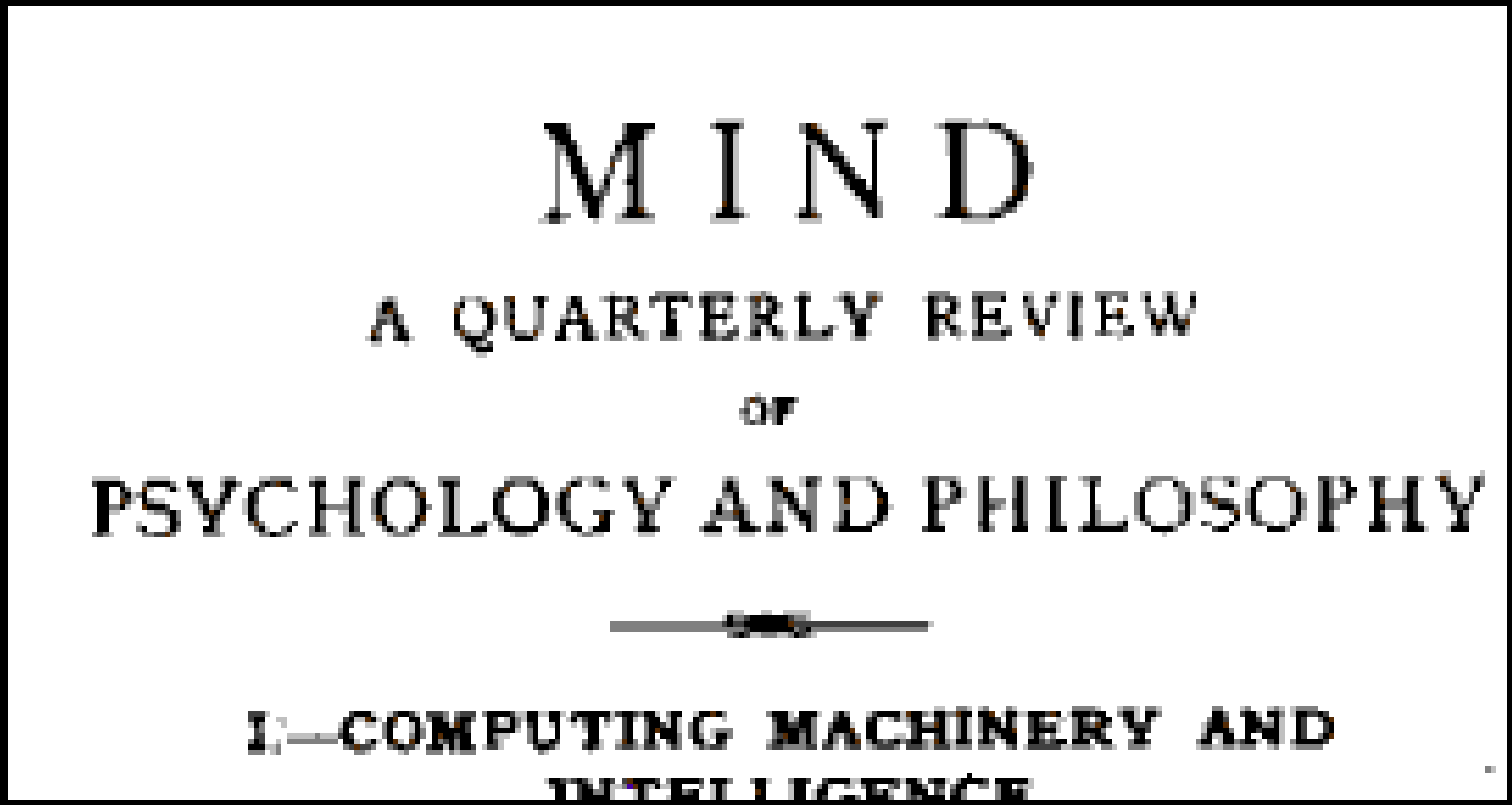
…and of course…



MIND

A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND

Turing

Alan and I