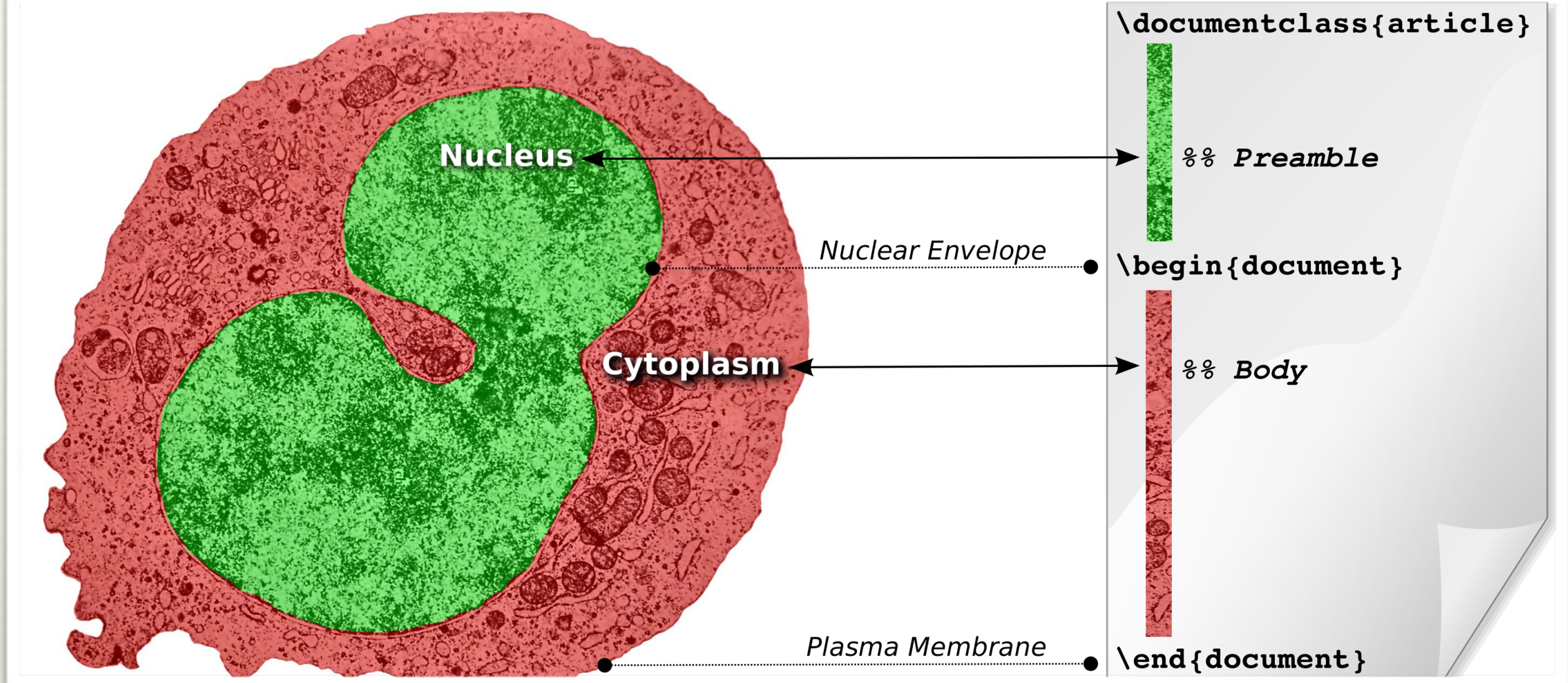

Didier Verna, EPITA Research Lab.

ACCU 2014, Friday April 11th

Biological Realms in Computer Science

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Prologue


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Part I: Origins

1. Transversality

Understanding **Unification**

" It is a requirement to the human brain to put order in the universe. […] One may disagree with explanatory systems offered by myths or magic, but one cannot deny them coherence. "

—*François Jacob*

1. Transversality

Understanding **Unification**

" The heart of the problem is always to explain the complicated visible by some simple invisible. "

—Jean Perrin

1. Transversality

Understanding **Unification**

- Science ≠ Religions or Myths
- Experimentation: confront the possible with the actual
- Parceling: experimentation on small problems

1. Transversality

Understanding **Unification**

" The beginning of modern science can be dated from the time when such general questions as 'How was the universe created?' […] were replaced by such limited questions as 'How does a stone fall?'. Scientific knowledge thus appears to consist of isolated islands. "

—François Jacob

1. Transversality

Understanding **Unification**

" In the history of sciences, important advances often come from bridging the gaps. They result from the recognition that two hitherto separate observations can be viewed from a new angle and seen to represent nothing but different facets of one phenomenon. "

—François Jacob

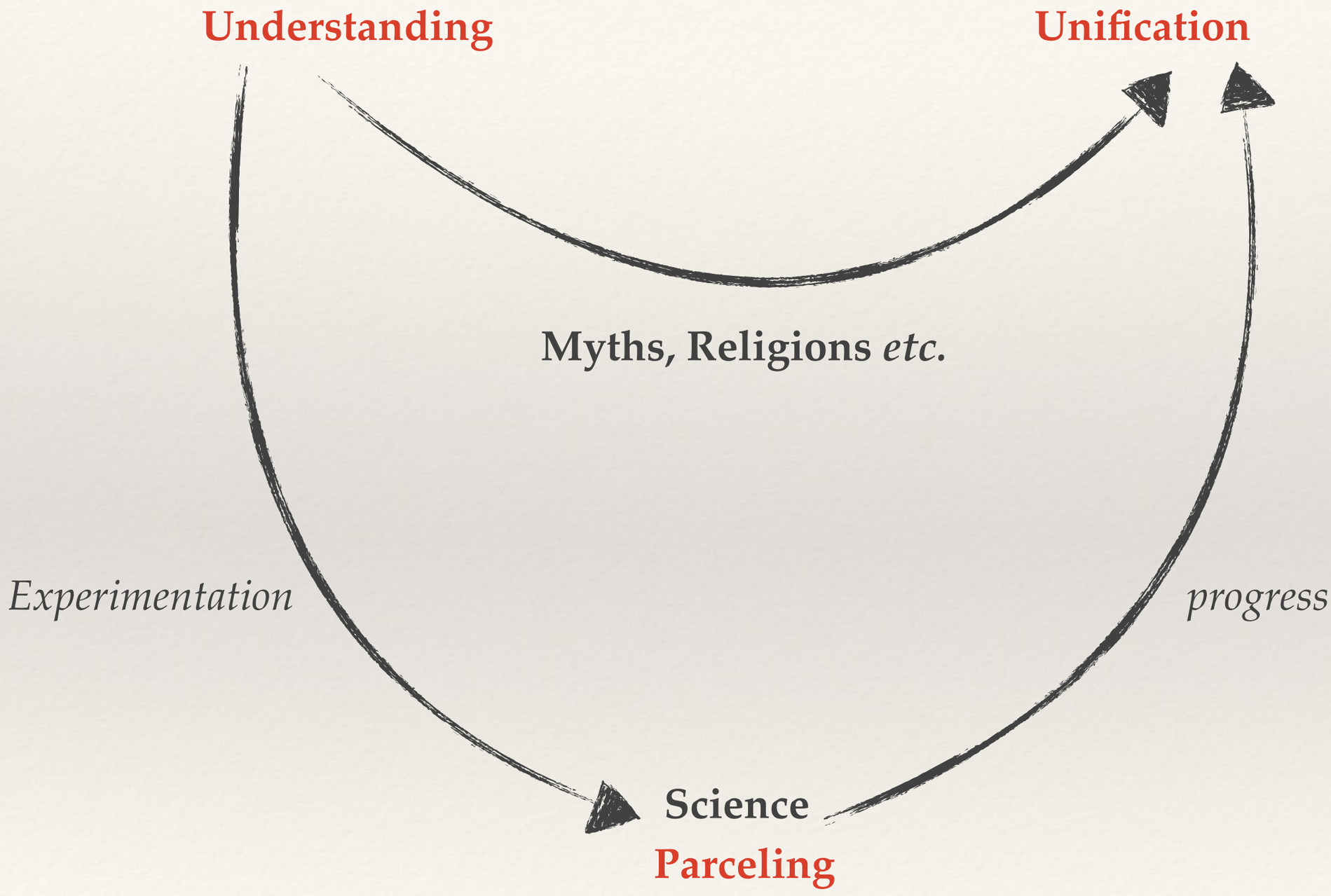
1. Transversality

Understanding **Unification**

"As Science progresses, there is a steady decrease in the number of postulates on which it has to rely for its development."

—*Antoine Danchin*

1. Transversality



2. Transversal Models

Beyond Science

" We were all so excited we literally rushed to the book store. When I arrived there, the queue already extended outside the store, up to the pavement. "

— *Lida Rising on the GoF book*

2. Transversal Models

Beyond Consciousness

" Many of the concepts and techniques presented in this paper could find wide applications outside the specific area of software systems, in other industries, and to the social and economic systems. "

— *Lehman on software evolution*

2. Transversal Models

Networks and Complex Systems

" The greatest challenge today, not just in cellular biology and ecology but in all of science, is the accurate and complete description of complex systems. "

— *Edward O. Wilson*

2. Transversal Models

Networks and Complex Systems

" In the longer run, network thinking will become essential to all branches of science, as we struggle to interpret the data pouring in from neurobiology, genomics, finance and the World Wide Web. "

— *Steven H. Strogatz*

2. Transversal Models

Networks and Complex Systems

" […] fundamental scientific challenge: understanding the laws of nature that unite evolved and engineered systems. "

—*Uri Alon*

3. From Computer Science to Biology

- Turing machine metaphor / macrocellular complexity
  (Carl Woese, 1972)
- …
- « in-silico » experiments / protein functions study
  (Lakshminarayan M. Iyer, 2001)
- Graph theories / transcriptional regulatory networks
  (Uri Alon, 2007)

4. From Biology to Computer Science

- Object-Oriented Programming

" It was probably in 1967 when someone asked me what I was doing, and I said: « It's object-oriented programming. » […] I thought of objects being like biological cells and/or individual computers on a network, only able to communicate with messages. "

— *Alan Kay*

4. From Biology to Computer Science

- Object-Oriented Programming
- Artifical Intelligence in General
- Neural Networks
- Genetic Algorithms
- Computer Viruses

5. Discovery *vs.* Invention

- **Genetic Program (1960)**
  Distinct from the cell (Cf. Turing & Von Neumann)
  Genome transplantation
  Cellular computers
  Genetic engineering

- **Biological Networks (2003)**
  Good engineering principles such as Modularity, Robustness, Redundancy.

6. Tinkerers *vs.* Engineers

" [Natural selection] works like a tinkerer — a tinkerer who does not know exactly what he is going to produce. […] Evolution behaves like a tinkerer who, during eons upon eons would slowly modify his work […] to adapt it progressively to its new use. "

— *François Jacob*

6. Tinkerers *vs.* Engineers

" Evolution is far from perfection. This is a point which was repeatedly stressed by Darwin who had to fight against the argument of perfect creation. In Origin of Species (1859), Darwin emphasises over and over again the structural or functional imperfections of the living world. "

— *François Jacob*

6. Tinkerers *vs.* Engineers

" The action of natural selection has often been compared to that of an engineer. This, however, does not seem to be a suitable comparison […] because the engineer works according to a pre-conceived plan [and] because the objects produced by the engineer, at least by the good engineer, approach the level of perfection made possible by the technology of the time. "

— *François Jacob*

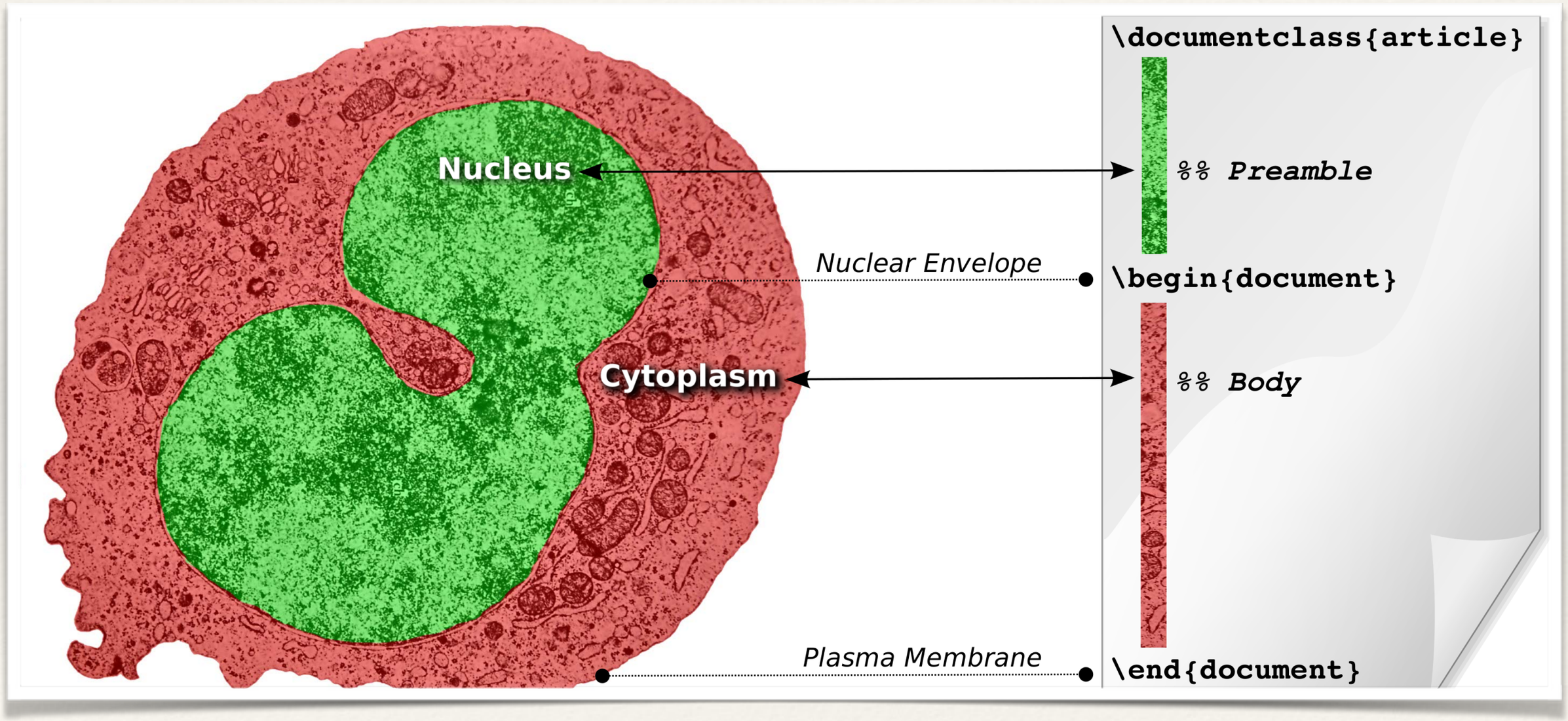
7. The trigger

" [LaTeX] is a wildly inconsistent mishmash and hotchpotch of ad-hoc primitives and algorithmic solutions without noticeable streamlining and general concepts. A thing like a pervasive design or elegance is conspicuously absent. You can beat it around to make it fit most purposes, and even some typesetting purposes, but that is not perfection. "

— *David Kastrup*

7. The trigger

Sometimes, we are much more tinkerers than we are engineers



Part II: Ascension

8. The Engineer as a Tinkerer

- Nature works by tinkering, as opposed to engineering
  (François Jacob, 1977)
- There are engineering principles in biological systems
  (Uri Alon, 2003)
- Genetic code ≡ software program
  (Antoine Danchin, 2009)

8. The Engineer as a Tinkerer

There is a lot of tinkering in what we do!

" The program of molecular biology is reverse-engineering on a grand scale. "

— *Uri Alon*

" The program of computer science should be reverse-tinkering on a grand scale. "

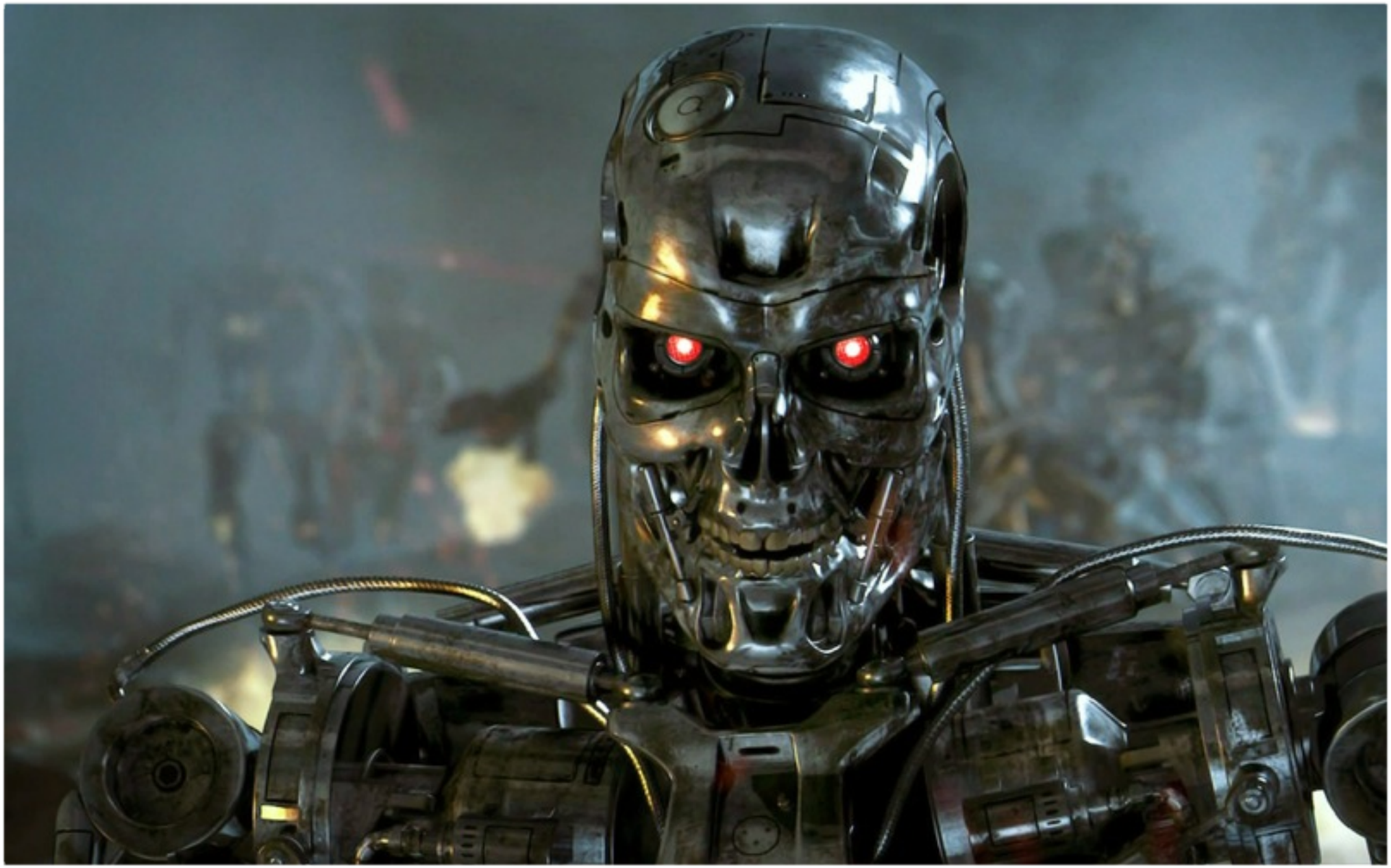
— *My Self*

8. The Engineer as a Tinkerer

" As programmers, we like to think of software as the product of our intelligent design, carefully crafted to meet well-specified goals. In reality, software evolves inadvertently through the actions of many individual programmers, often leading to unanticipated consequences. Large complex software systems are subject to constraints similar to those faced by evolving biological systems, and we have much to gain by viewing software through the lens of evolutionary biology. "

— *Stephanie Forrest*

9. Determinism *vs.* Predictability



9. Determinism *vs.* Predictability

Deterministic Chaos / Butterfly Effect (Lorentz)

" In the last few decades, physicists have become aware that even the systems studied by classical mechanics can behave in an intrinsically unpredictable manner. Although such a system may be perfectly deterministic in principle, its behavior is completely unpredictable in practice. "

— *Francis P. Heylighen*

9. Determinism *vs.* Predictability

Behavioral Intercession / Reflexivity

- Deterministic Molecular Biology *vs.* Reductionism
- Adaptive Mutations *vs.* Randomness

10. Predictability *vs.* Control

" We feel we are in control of our current software applications because they are the result of a conscious design process based on explicit specifications and they undergo rigorous testing. "

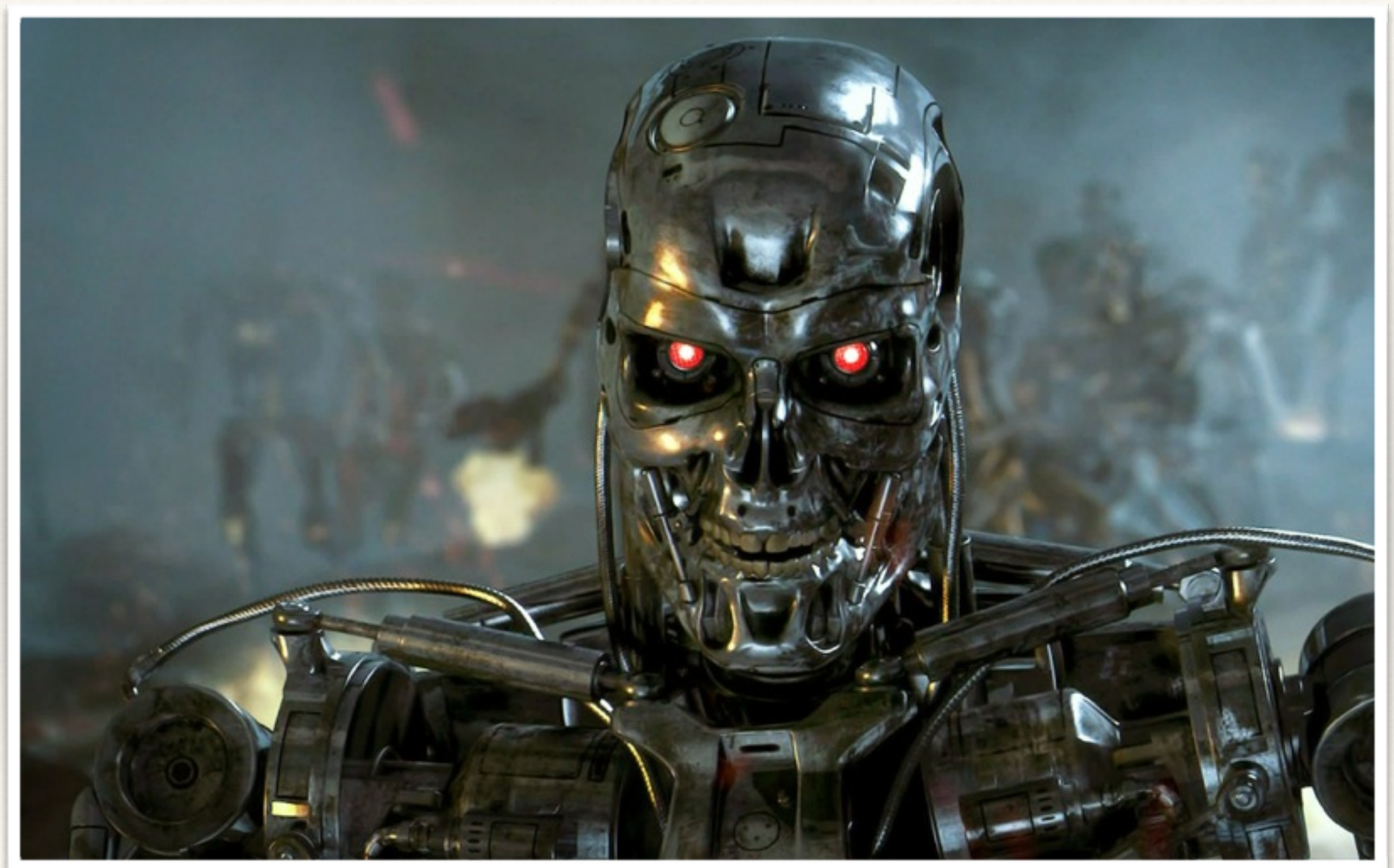
— *Gabriel / Goldman*

10. Predictability *vs.* Control

" The programmer moves in a world entirely of his own making. [. . .] [His] excitement rises to a fevered pitch when he is on the trailof a most recalcitrant error […]. It is then that the system the programmer has created gives every evidence of having taken on a life of its own, and certainly, of having slipped from his control. [. . .] For, under such circumstances, the misbehaving artifact is, in fact, the programmer's own creation. "

— *Weizenbaum*

11. Rise of the Machines



11. Rise of the Machines

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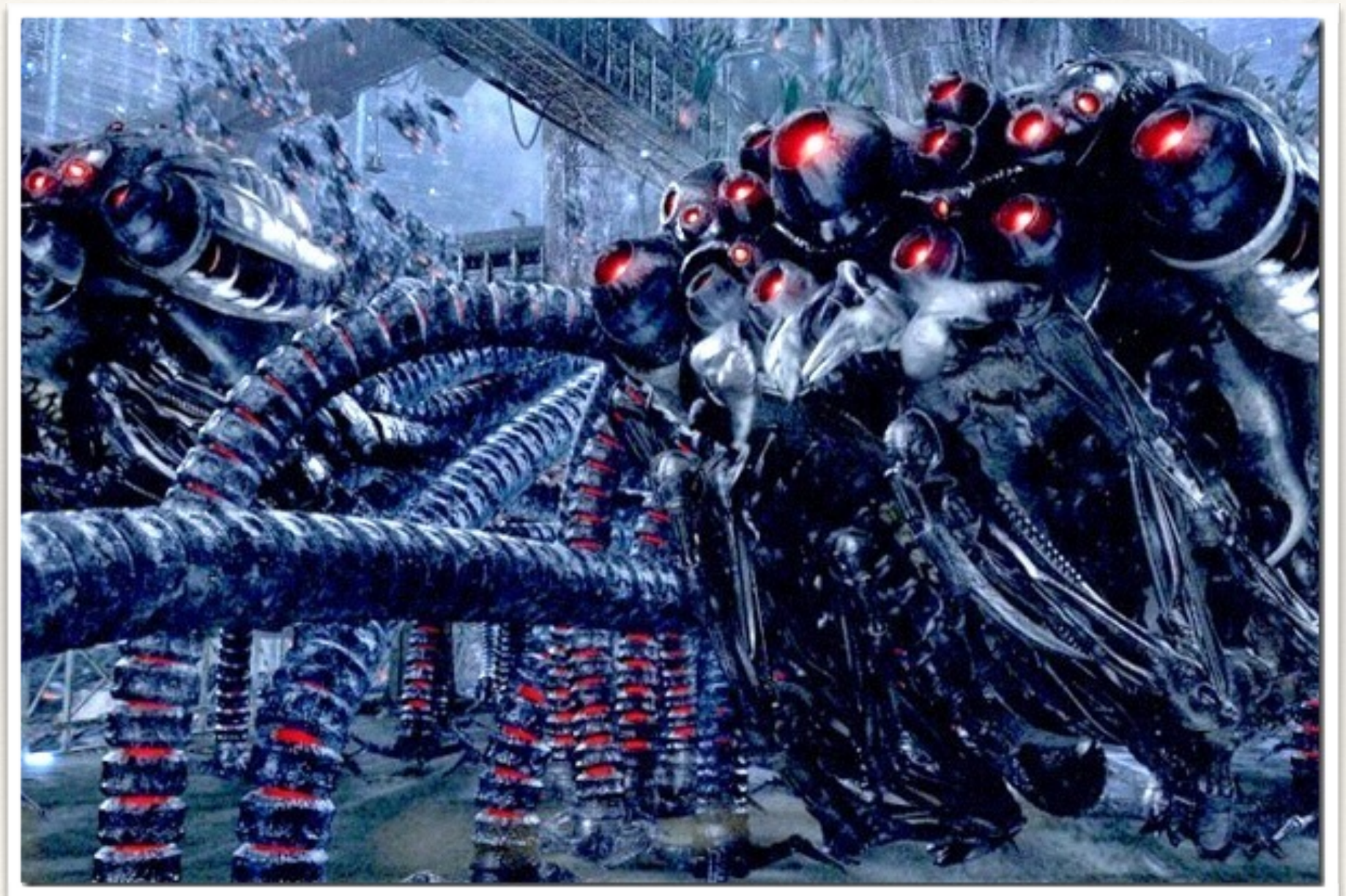


11. Rise of the Machines

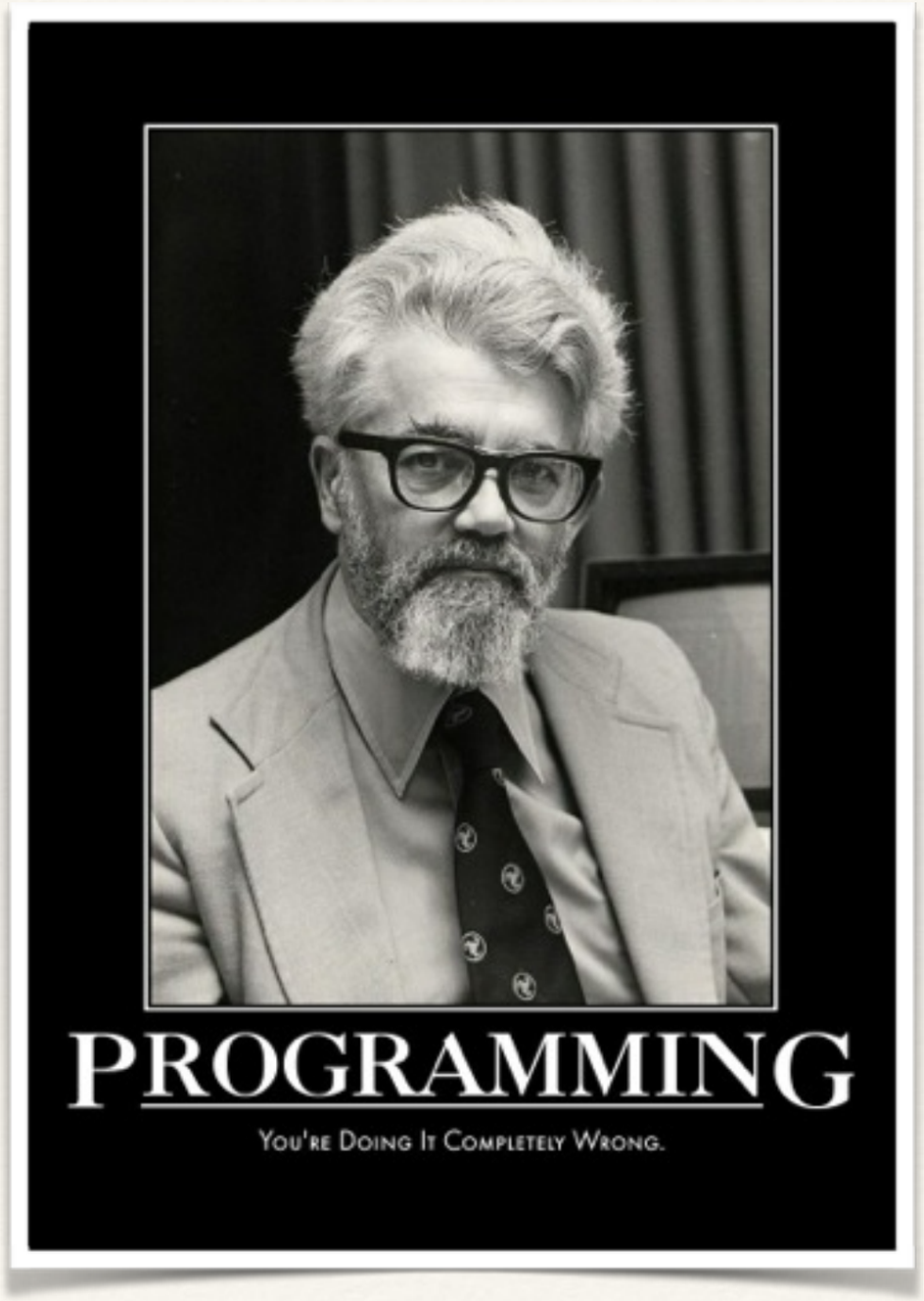
11. Rise of the Machines

Autopoiesis (Maturana)

" The paleome includes a set of genes that are not essential for life under laboratory growth conditions. Many of these genes code for maintenance and repair, and may be involved in perpetuating life by restoring accuracy and even creating information during the reproduction process. "

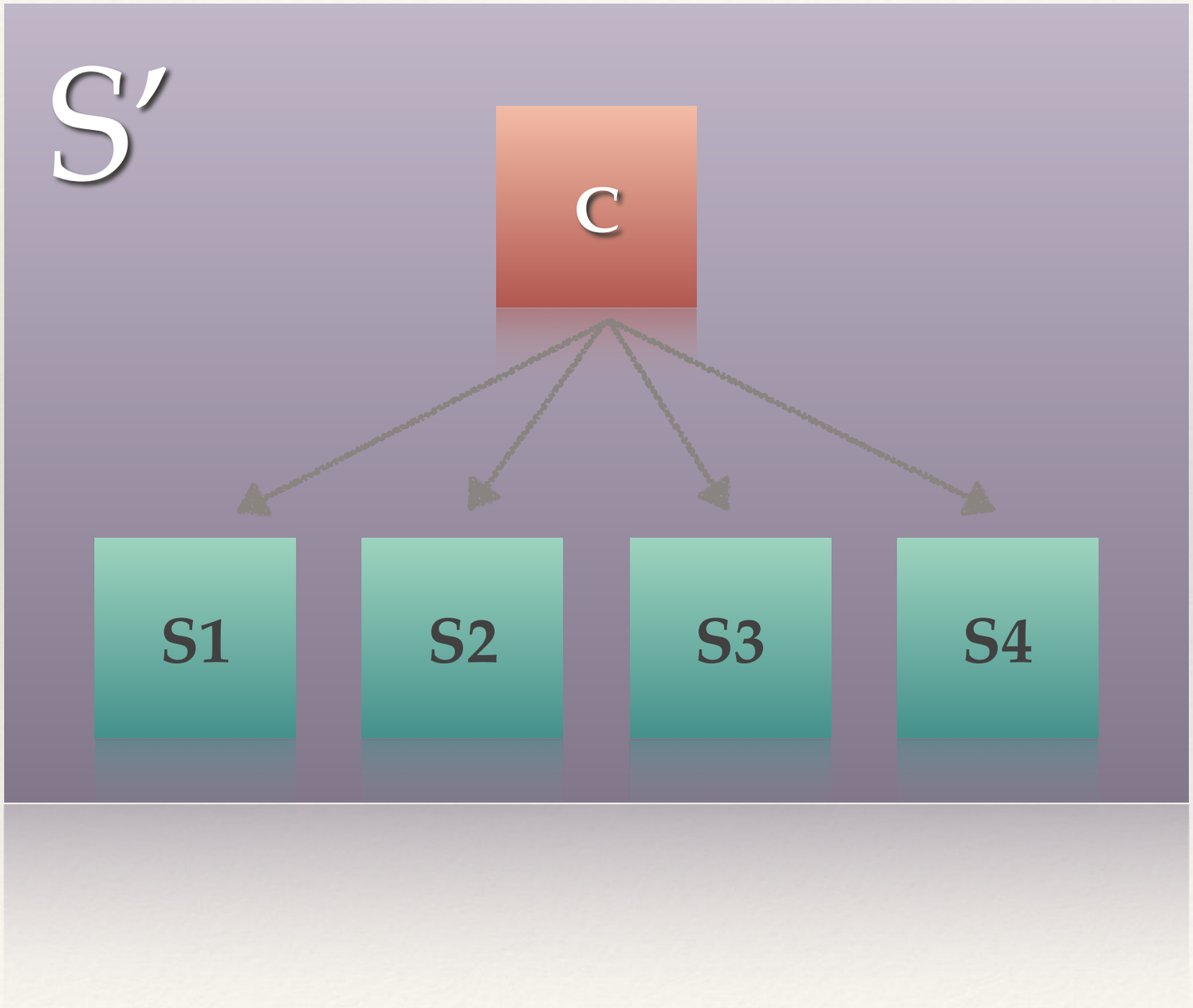
— *Antoine Danchin*

12. Darwin's Radio



12. Darwin's Radio

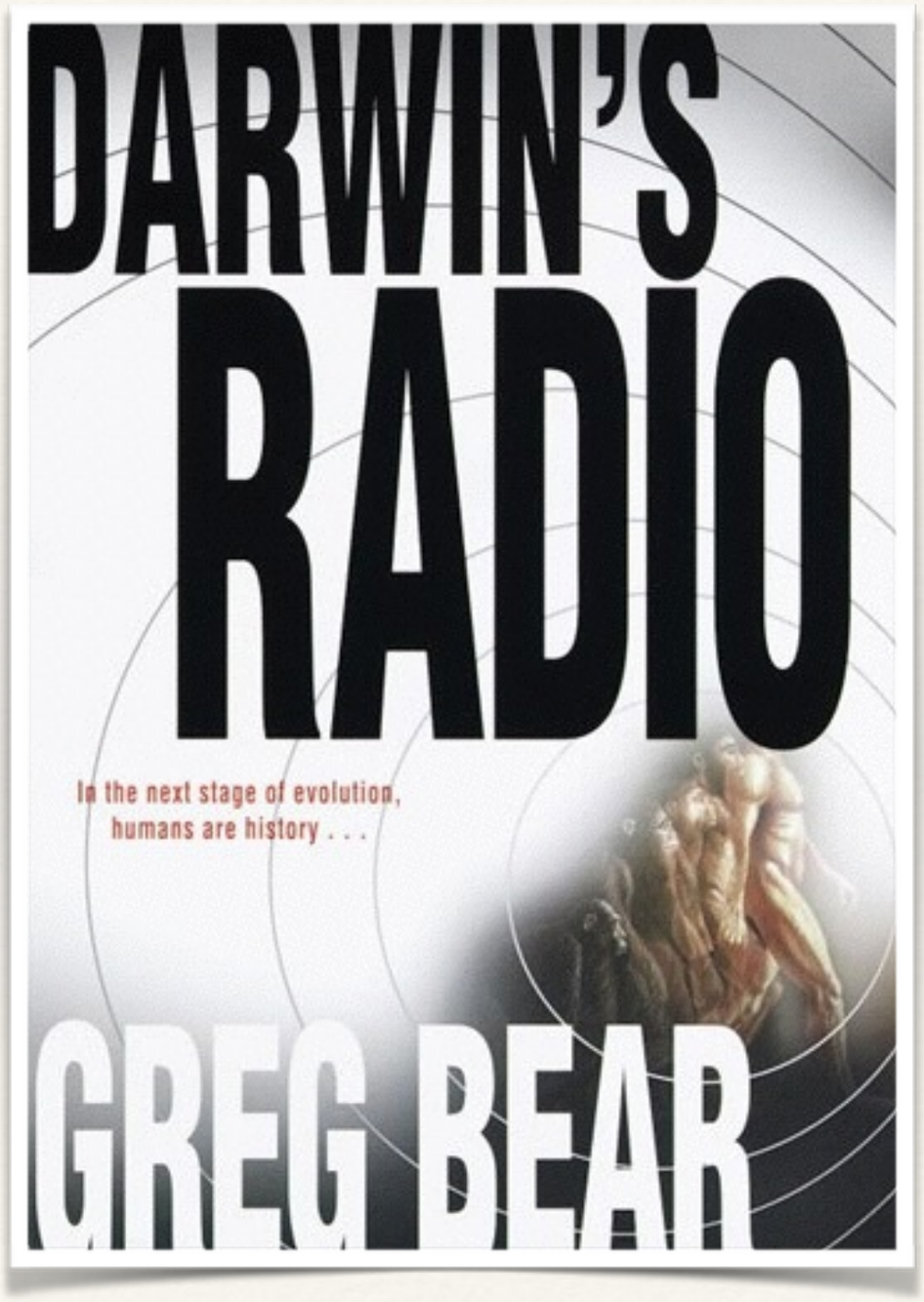
Meta-System Transitions (Valentin Turchin)



12. Darwin's Radio

" Most of the time this complexity increase, and evolution in general, occurs rather slowly or continuously, but during certain periods evolution accelerates spectacularly. This results in changes which from a long term perspective may be viewed as momentous events, separating discrete types of organization. "

12. Darwin's Radio



Epilogue

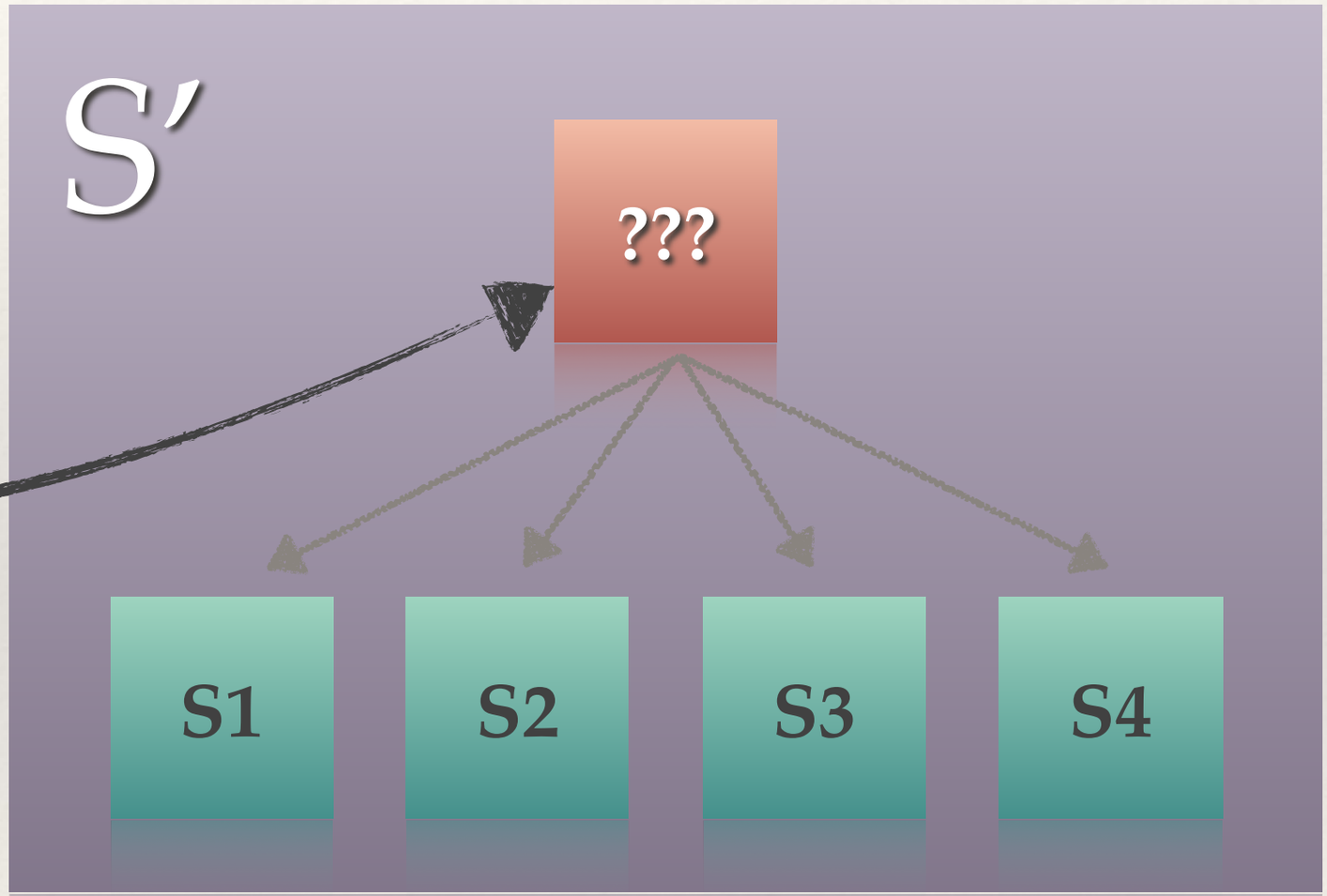
Facts

- Nature is engineered as much as software is tinkered
- Computer Science may be a discovery, not an invention
- The Great Paradox™

Epilogue

Questions

- Do we really want to let go of control ?
- What do we put in there ?



Thank You!

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