# More Is Different

Broken symmetry and the nature of
the hierarchical structure of science.

P. W. Anderson

Anderson, 1972

In 1929 Paul A. M. Dirac claimed that "the underlying physical laws necessary for the mathematical theory of ... the whole of chemistry are thus completely known, and the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble." This sentence of Dirac's is cited frequently by historians and

Dirac, 1929

“Everything that living things do can be understood in terms of the jiggling and wiggling of atoms.” – Richard Feynman in the seminal Feynman Lectures on Physics, 1963. Living systems are in a state of perpetual motion. 27 Oct 2015

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The PLOS Comp Biol Macromolecular Structure and ...

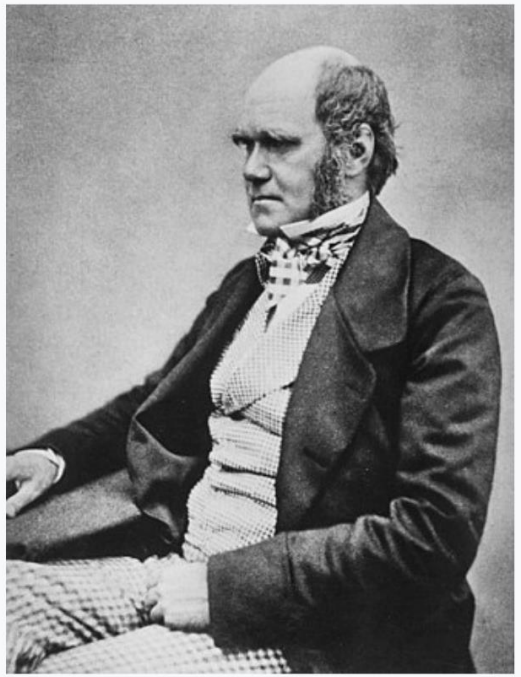
Feynman, 1963

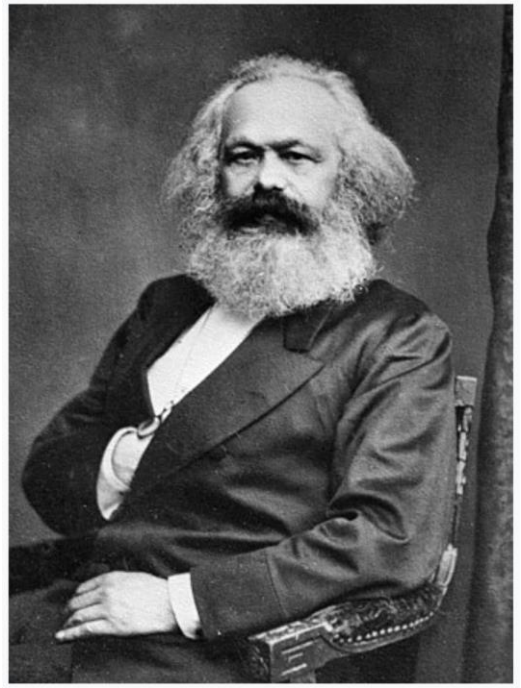
# Quote 1

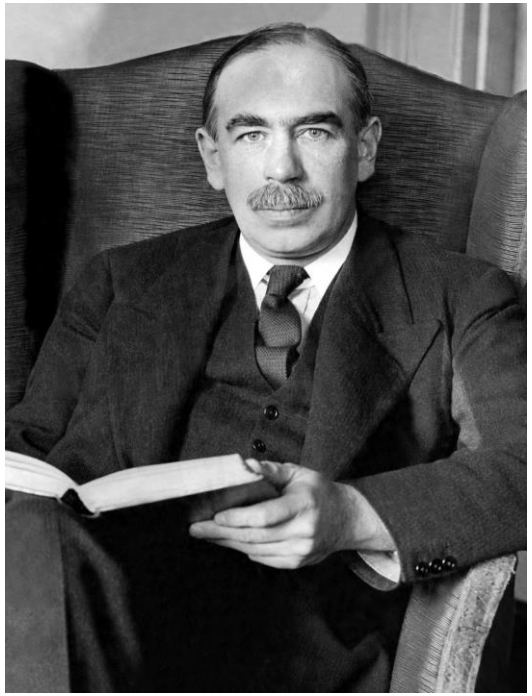
| X | Y |
| --- | --- |
| solid state or many-body physics | elementary particle physics |
| chemistry | many-body physics |
| molecular biology | chemistry |
| cell biology | molecular biology |
| • | • |
| • | • |
| • | • |
| psychology | physiology |
| social sciences | psychology |

But this hierarchy does not imply that science X is "just applied Y." At each stage entirely new laws, concepts, and generalizations are necessary, requiring inspiration and creativity to just as great a degree as in the previous one. Psychology is not applied biology, nor is biology applied chemistry.

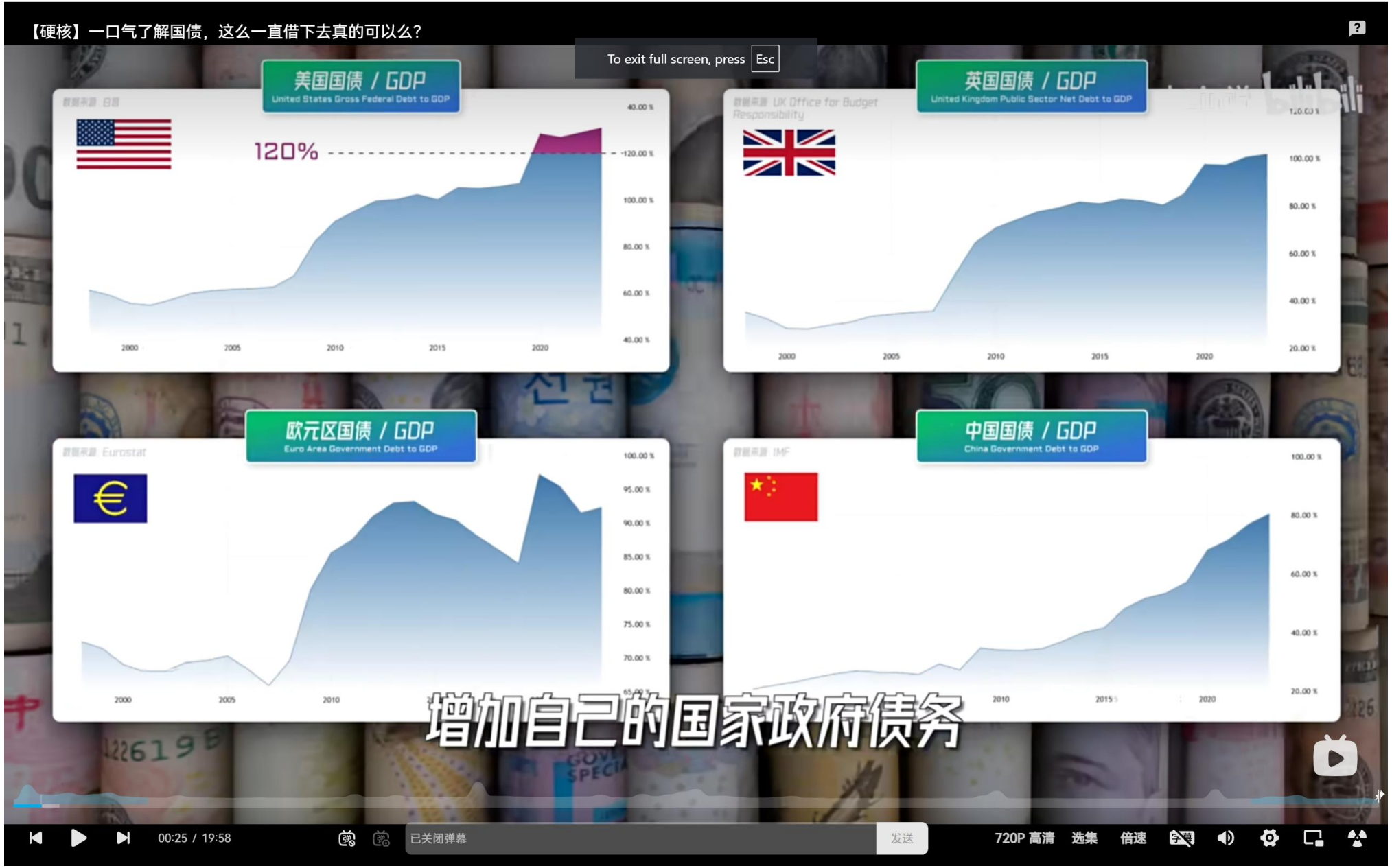
Anderson, 1972







Figures from Wikipedia




From [Lindsay]

# Quote 2

The main fallacy in this kind of thinking is that the reductionist hypothesis does not by any means imply a "constructionist" one: The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe. In fact, the more the elementary particle physicists tell us about the nature of the fundamental laws, the

Anderson, 1972

# Questions

1. Why Is AlexNet Far Better than LeNet?
2. Why Is Transformer Far Better than RNN?
3. Why Is RLHF So Successful?
4. Why Is Chain of Thought So Successful?

# Answers

1. We Need New Math Tools.
2. We Humanity Can Not Understand.