



When We Say  
“COMPLEXITY”  
What Do We Mean?



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[Sitpor.org/Abbas](http://Sitpor.org/Abbas)

# Overview

*“I think the next [21st] century will be the century of complexity. We have already discovered the basic laws that govern matter and understand all the normal situations. We don’t know how the laws fit together, and what happens under extreme conditions. But I expect we will find a complete unified theory sometime this century. There is no limit to the complexity that we can build using those basic laws.”*

Stephen W. Hawking, in answer to a question: Some say that while the twentieth century was the century of physics, we are now entering the century of biology. What do you think of this?

# Overview

*"Science has explored the microcosmos and the macrocosmos; we have a good sense of the lay of the land. **The great unexplored frontier is complexity.**"*

*- Heinz Pagels, The Dreams of Reason*



*From Wikipedia*

**First,**

**Simplicity:**

# Overview

- *“Truth is ever to be found in simplicity, and not in the multiplicity and confusion of things.”* Sir Isaac Newton
- *“Everything should be made as simple as possible, but no simpler.”* Albert Einstein
- *“You can recognize truth by its beauty and simplicity.”* R. Feynman



## **FRANK WILCZEK**

Frank Wilczek, Professor of Physics at MIT, was awarded the Nobel Prize in Physics in 2004.

OCT 14, 2015 26

English



# Why Is Physics Beautiful?

Tweet



98

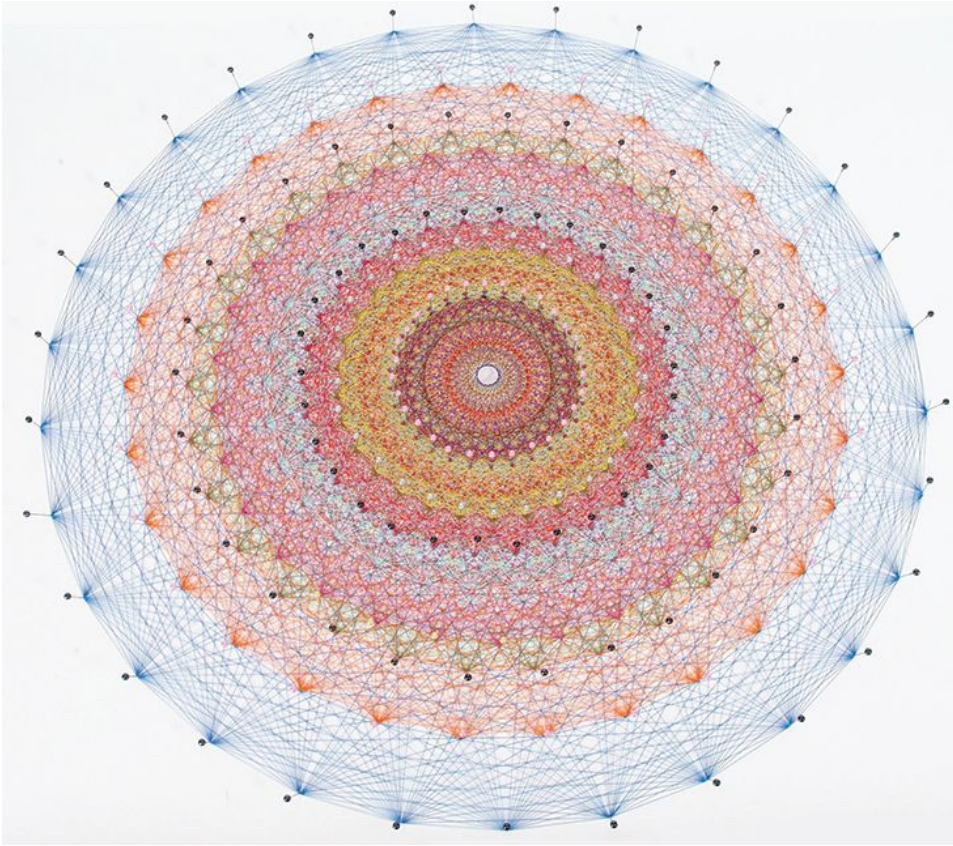


55

CAMBRIDGE – The nineteenth-century physicist Heinrich Hertz once described his feeling that James Clerk Maxwell’s equations, which depict the fundamentals of electricity and magnetism, “have an independent existence and an intelligence of their own, that they are wiser...even than their discoverers, that we get more out of them than was originally put into them.”

## UNIVERSAL BEAUTY:

The  $E_8$  Lie group, pictured above, is a perfectly symmetrical 248-dimensional object. (Lie groups are used in math and physics to model symmetries.) Symmetry, Frank Wilczek says, is prominent in the fundamental laws of nature, and “connotes harmony and beauty.”






<http://nautil.us/issue/32/space/beauty-is-physics-secret-weapon>

Murray Gell-Mann:

# Beauty, truth and ... physics?

TED2007 · 16:02 · Filmed Mar 2007

 27 subtitle languages 

 View interactive transcript



[https://www.ted.com/talks/murray\\_gell\\_mann\\_on\\_beauty\\_and\\_truth\\_in\\_physics](https://www.ted.com/talks/murray_gell_mann_on_beauty_and_truth_in_physics)

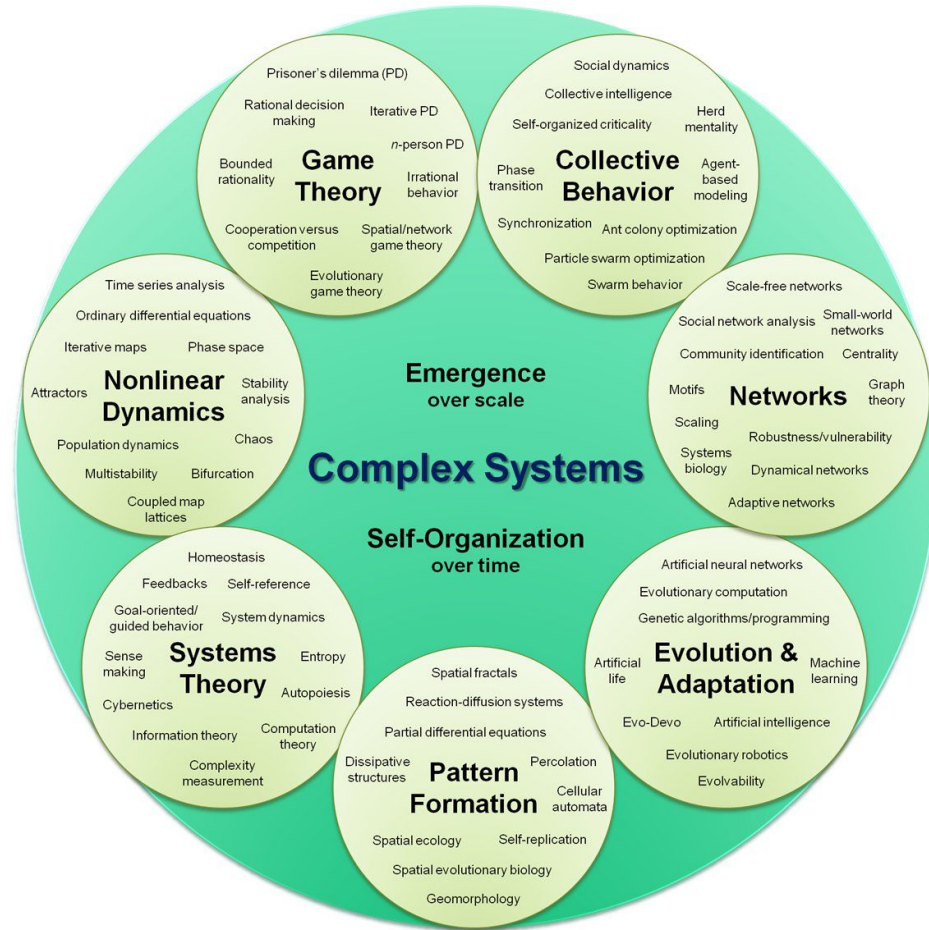


**Back to  
COMPLEXITY:**



# We have nothing better to show yet!

From Wikipedia



## What is a Complex System?

James Ladyman, James Lambert

*Department of Philosophy, University of Bristol, U.K.*

Karoline Wiesner

*Department of Mathematics and Centre for Complexity Sciences, University of Bristol, U.K.*

(Dated: March 8, 2012)

Complex systems research is becoming ever more important in both the natural and social sciences. It is commonly implied that there is such a thing as a complex system, different examples of which are studied across many disciplines. However, there is no concise definition of a complex system, let alone a definition on which all scientists agree. We review various attempts to characterize a complex system, and consider a core set of features that are widely associated with complex systems in the literature and by those in the field. We argue that some of these features are neither necessary nor sufficient for complexity, and that some of them are too vague or confused to be of any analytical use. In order to bring mathematical rigour to the issue we then review some standard measures of complexity from the scientific literature, and offer a taxonomy for them, before arguing that the one that best captures the qualitative notion of the order produced by complex systems is that of the Statistical Complexity. Finally, we offer our own list of necessary conditions as a characterization of complexity. These conditions are qualitative and may not be jointly sufficient for complexity. We close with some suggestions for future work.

*From now on;  
All the pictures are  
from Wikipedia*

# Complex Systems and Their Features

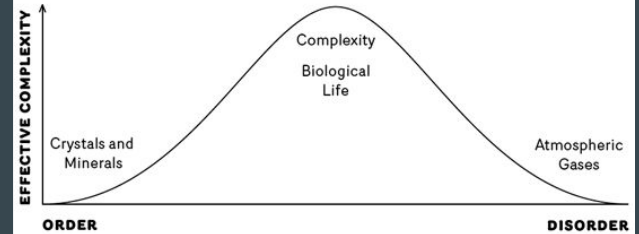
## Non-linearity



## Feedback

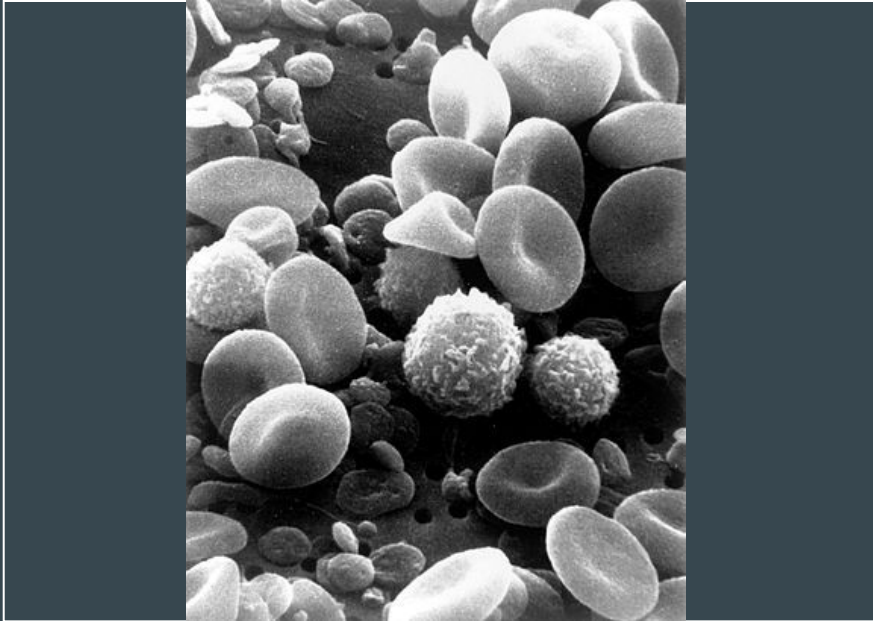


## Spontaneous Order

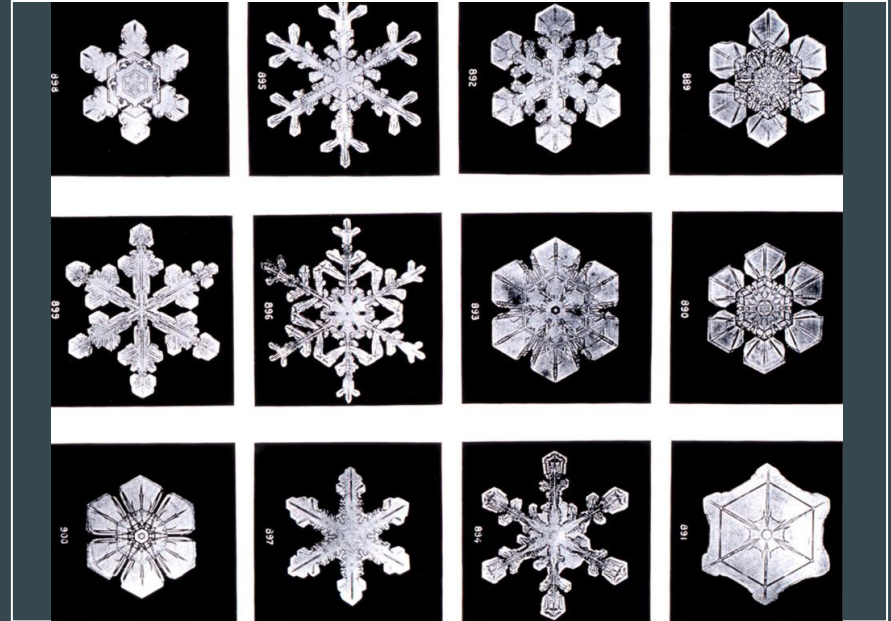


# Complex Systems and Their Features

## Robustness and lack of Central Control



## Emergence



# Emergence



Birds flocking  
emerges from  
simple rules:

1. keep distance
2. stay aligned
3. avoid predators.

# Emergence



Conus textile exhibits an emergent cellular automaton pattern on its shell.

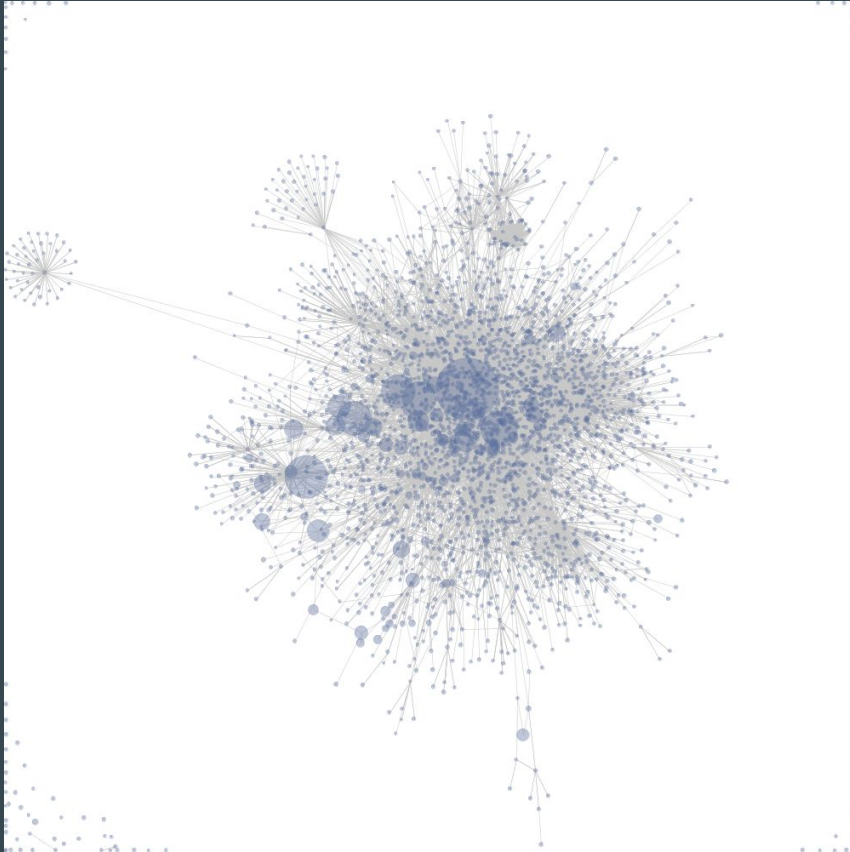


# Emergence



Persian Leopard  
Think about its skin!

# Emergence



Visualization of links  
between pages on a wiki.

See:  
*emergence of giant  
component*

## Emergence In Physics

for *Routledge Encyclopedia of Philosophy Online*

Robert W. Batterman

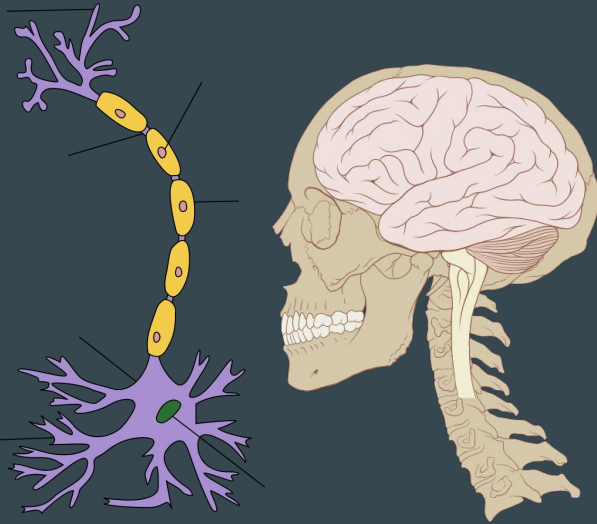
### Emergence in Physics

The concept of emergence in philosophical discussions is closely connected with the notions of antireductionism, unpredictability, and novelty. In many cases these latter concepts are explicated in mereological terms. Very crudely, something is emergent when it (the whole) is greater than the sum of its parts. Alternatively, the behavior of the emergent whole does not reduce to some function of the behavior of its components. Or, the behavior of the emergent whole is unpredictable given knowledge of the nature of its parts. Or, finally, the behavior of the emergent whole is completely different, new, and unexpected, given knowledge of the nature of its parts. In addition, there is often, again in philosophical contexts, a demand that the emergent feature is not *explainable*, by a theory of the nature of its parts.

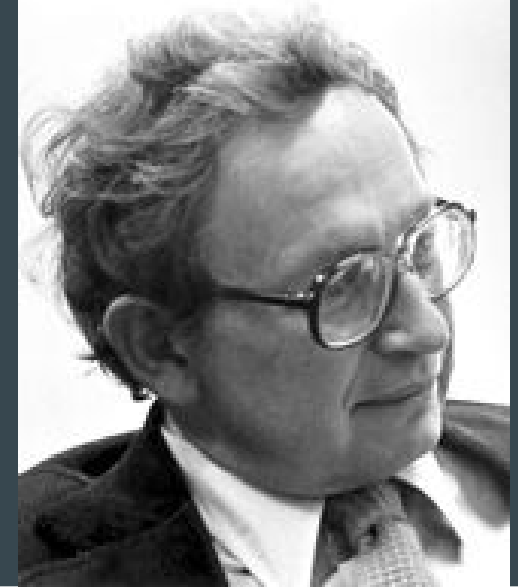
Most philosophical discussions focus on the notion of emergence in the context of the mind/body problem, broadly construed: How can the mental, with all of its unique attributes, possibly obtain in a world in which the basic fundamental features are characterized by physical theory. This problem of emergence is intimately connected with the position called nonreductive physicalism.

# Complex Systems and Their Features

## Hierarchical Organisation



## Numerosity



# سیستم‌های پیچیده: «ماهیت و ویژگی»

ژانویه 17، 2017 BY عباس کریمی · COMMENTS 3

[Sitpor.org](http://Sitpor.org)



## پیچیدگی چیست؟!



حدود ۳۳۰ سال پیش، نیوتون با انتشار شاهکار خود، اصول ریاضی فلسفه طبیعی، نگاهی جدید نسبت به بررسی طبیعت را معرفی کرد. نگاه نیوتون به علم به کمک نظریه الکترومغناطیس که توسط ماکسول جمع بندی و در نهایت توسط آلبرت اینشتین کامل شد، شالوده **فیزیک کلاسیک** را بنا نهاد. انقلاب بعدی علم، توسط مکانیک کوانتومی رخ داد. آنچه که مکانیک کوانتومی در قرن ۲۰ میلادی نشانه گرفت، مسئله موضعیت در فیزیک کلاسیک و نگاه احتمالاتی به طبیعت بود. نگاهی که سرانجام منجر به پارادایمی جدید در علم، به عنوان **فیزیک مدرن** شد. با این وجود، علی‌رغم پیشرفت‌های خارق‌العاده در **فیزیک** و سایر علوم، کماکان در توجیه بسیاری از پدیده‌ها و مانده‌ایم. پدیده‌هایی که همیشه اطرافمان حاضر بوده‌اند ولی هیچ‌موقع قادر به توجیه رفتار آن‌ها نبوده‌ایم. بنابراین، می‌توان به این فکر کرد که شاید در نگاه ما به طبیعت و مسائل علمی، نقصی وجود داشته باشد. به دیگر سخن، بعید نیست که مجدداً نیاز به بازنگری در نگاهمان به طبیعت (تغییر پارادایم) داشته باشیم؛ عده زیادی معتقدند آنچه که در قرن ۲۱م نیاز است، نگاهی جدید به مبانی علم است؛ نگاه پیچیدگی!



گاهی گفته می‌شود که ایده پیچیدگی، بخشی از چهارچوب اتحاد بخشی برای علم و انقلابی در فهم ما از سیستم‌هایی مانند مغز انسان یا اقتصاد جهانی است که رفتار آن‌ها به‌سختی قابل **پیش‌بینی** و **کنترل** است. به همین خاطر، سوالی مطرح می‌شود: **آیا چیزی به عنوان «علم پیچیدگی» وجود دارد یا اینکه پیچیدگی متناظر با هر شاخه‌ای از علم، دارای شیوه خاص خود است و مردم در رشته‌های مختلف مشغول سر و کله زدن با سیستم‌های پیچیده زمینه کاری خود هستند؟! به عبارت**

# To be discussed later:

- **COMPLEXITY, INFORMATION,  
AND PROBABILITY**
  - **MEASURES OF COMPLEXITY**
  - **THE “PEAKED” COMPLEXITY  
FUNCTION**
  - **THE FEATURES OF COMPLEX  
SYSTEMS REVISITED**
-

*Let's think again;*

**What is Science?**

**What is Physics?**

**Who is a wise policy maker?!**

**Thank You**