

COMPLEXITY & THRESHOLDS

13.7 billion years ago

5 billion years ago

1 billion years ago

1 million years ago

Stars die and create heavier elements
The first stars and galaxies
Hydrogen and helium form
The Big Bang

Our Solar System forms
Life appears
Photosynthesis

The first eukaryotes
Life leaves the sea
First brains develop
Cambrian Explosion
Multicelled organisms

Homonids appear
Asteroid impact triggers extinction
Dinosaurs and mammals appear

BIG HISTORY PROJECT

900L

COMPLEXITY & THRESHOLDS

By David Christian

What does complexity mean,
and why is it so important?
What role has complexity
played in getting us to the
world we live in today?

One of the central themes of this course is the idea of increasing complexity. In the 13.8 billion years since our Universe appeared, more and more complex things seem to have appeared — and we're among the most complex of them all. So it's natural for complex things to fascinate us. Besides, modern human society is so complex that learning how the Universe creates complexity can also teach us something about today's world. But we shouldn't assume there's anything special about complexity or that complex things are necessarily any better than simple things. Remember that complexity can present challenges.

What does complexity mean?

That's a tough question and there's no universally accepted answer. We may feel intuitively that empty space is much simpler than a star, or that a human being is in some sense more complex than an amoeba. But what does that really mean? Here are some ideas that may help you think about complexity during this course.

A continuum from simple to complex

Complexity is a quality, like "hot" or "cold." Things can be more or less simple and more or less complex. At one end is utmost simplicity, like the cold emptiness of intergalactic space. At the other extreme is the complexity of a modern city.

The qualities of more complex things

Here are three qualities that make some things more complex than others.

- 01 **Diverse ingredients:** More complex things often have more bits and pieces, and those bits and pieces are more varied.
- 02 **Precise arrangement:** In simpler things it doesn't matter too much how the ingredients are arranged, but in complex things the bits and pieces are arranged quite precisely. Think of the difference between a car and all the bits and pieces of that car after it's been scrapped and is lying in a junkyard.
- 03 **Emergent properties:** Once the ingredients are arranged correctly, they can do things that they couldn't do when they weren't organized. A car can get you around; its component parts cannot. A car's capacity to be driven is a quality that "emerges" once it's been assembled correctly, which is why it's called an "emergent property."

Complexity is fragile

There's another important thing to remember about complexity. Complex things need just the right ingredients and they need to be assembled in just the right way. So, complex things are usually more fragile than simple things. And that means that after a time, they fall apart. If they are living creatures, we say they "die." Death, or breakdown, seems to be the fate of all complex things, though it may take billions of years for a star to break down, and just a day or two for a mayfly to die.

The Second Law of Thermodynamics

Creating complex things is more difficult than creating simple things. The natural tendency of the Universe seems to be for things to get less and less organized. Think of your own house if you just let it be for a month. Tidying your room means arranging everything in just the right way; it takes work. But if you don't care how it's arranged you can just let it un-tidy itself naturally. The idea that the Universe tends naturally to get less ordered and less complex is expressed in one of the most fundamental of all the laws of physics: the Second Law of Thermodynamics. That's one way of explaining why making complex things requires more work, and thus more energy, than making simple things.

Why complexity is rarer than simplicity

The Second Law of Thermodynamics explains why most of the Universe is simple. Intergalactic space is almost completely empty, extremely cold, and randomly organized. Complexity is concentrated in just in a few places: inside galaxies and particularly around stars.

Goldilocks Conditions

You find complex things only where the conditions are just right for making them, where there are just the right environments, just the right ingredients, and just the right energy flows. We call these conditions "Goldilocks Conditions." Remember the children's story of the three bears? Goldilocks enters their house when they are out. She tastes their porridge and finds that the father bear's is too hot, the mother bear's is too cold, but the baby bear's is just right. Complexity seems to appear only where the conditions are "just right." So whenever we see complex things appearing, we can ask why the Goldilocks Conditions were "just right."

Here's an example. You always need energy. So if there's no energy flowing, it's hard to build complexity. Think of a still, calm lake that's been dammed. Not much is happening. Then imagine opening the gates of the dam and allowing the water to flow downhill. Now you have energy flowing — enough to drive a turbine that can create the electricity to power a computer. Now more complex things can happen.

But of course there mustn't be too much energy. If there's too much water pressure then the turbine will be destroyed. So you need just the right amount of energy — not too little, not too much.

Thresholds of increasing complexity

In this course, we will focus on moments when more complex things seemed to appear, things with new emergent properties. We call these "threshold moments." Examples include the appearance of the first stars in a Universe that had no stars, and the appearance of the first cities in societies that had never known cities before.

Each time we cross one of these thresholds we'll ask about the ingredients and the Goldilocks Conditions. And we'll also ask what was new. What emergent properties do these new complex things have?

There are many such turning points in Big History, but in this course we will focus mainly on eight threshold moments. Some thresholds took place at a very specific point in time, while others were more gradual and we can only approximate the turning point. If this were an astronomy course or a biology course, our choice of thresholds would undoubtedly be different. In fact, during this course we will see many important "turning points" that we could, perhaps, describe as "thresholds."

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