



**Aim: How does Life depend on  
chaos?**

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# Objectives

- ✱ I can compare different definitions of Life.
- ✱ I can describe multiple characteristics of Life.
- ✱ I can explain how Life emerges from chaos.



If these words sound  
complicated...

CHAOTIC  
DISSIPATIVE SYSTEM  
SELF ORGANIZING  
FAR FROM EQUILIBRIUM  
COMPLEX  
FRACTAL  
FEEDBACK

...then let's backtrack a little.

# Let's begin with text book definitions for Life?

- ★ Life is a phenomenon that fulfills at least all the following characteristics:
  - ★ growth and development,
  - ★ reproduction,
  - ★ orderly pattern, and
  - ★ maintain homeostasis
- ★ It is the condition that distinguishes animals and plants from inorganic matter, including the capacity for growth, reproduction, functional activity, and continual change preceding death (Wikipedia, 2011).



**I will now proceed to  
explain *chaos*.**

# Let's begin by defining **chaos**.

☀ “The qualitative study of unstable aperiodic behavior in deterministic nonlinear dynamical systems.”

- Qualitative because it is a study of the qualities and not quantities.
- Aperiodic because no variable affecting the system undergoes a completely regular repetition of values (i.e. no patterns).
- Deterministic because it is governed by measurable physical forces making it predictable if all initial conditions and forces are known.
- Non-linear because the equations that express the phenomena are to a power other than 1 (e.g.  $x=2y+z$  vs.  $A=b^2+4c^3$ ; friction - feedback)
- Dynamic because it occurs while something is changing (i.e. flux in underwater sulfur vents)
- System because it is an entity with variable inputs and outputs that change with time.



# What are **nonlinear dynamic systems**?

- ★ The nonlinear dynamic systems studied by chaos theory are complex systems in the sense that a great many independent variables are interacting with each other in a great many ways.
- ★ **These complex systems have the ability to balance order out of chaos.**
- ★ This balance point is called the **edge of chaos** or **far from equilibrium**.

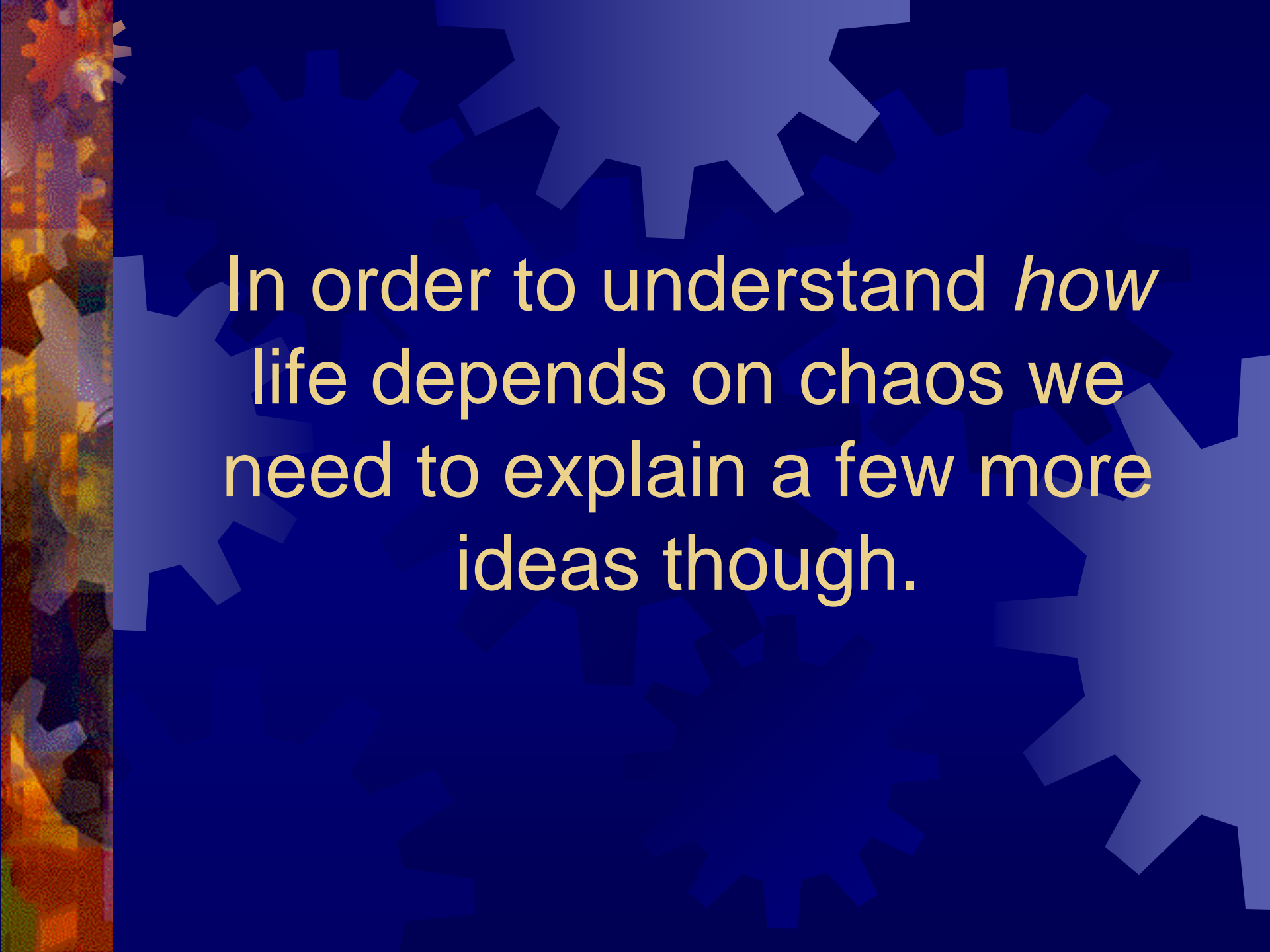
# What are **nonlinear dynamic systems**?

- ★ The process of self-organization happens spontaneously (*i.e.* origin of Life, a flock of birds taking off to fly and then spontaneously organizing themselves into a pattern.



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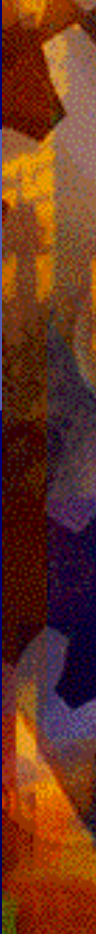
In order to understand *how*  
life depends on chaos we  
need to explain a few more  
ideas though.

# What is the concept *far from equilibrium*?

- ✴ Different than “in equilibrium” and “near equilibrium,” systems “far from equilibrium” have dramatically reorganized matter compared to their surroundings.
- ✴ There is a transformation from disorder - *thermal chaos* - into order.



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- ☀ What would happen if you were in equilibrium with your environment? For example, the air around you is relatively dry. What would happen if the water inside you started to equilibrate with the air around you? Can you think of other examples of how things in your body are far from equilibrium with the environment?



# What are **dissipative systems**?

- ☀ Systems that use *energy flow* to maintain their *form* are said to be *dissipative systems*.
- ☀ Examples are hurricanes, waves, and *living things*.



# What is **self organization**?

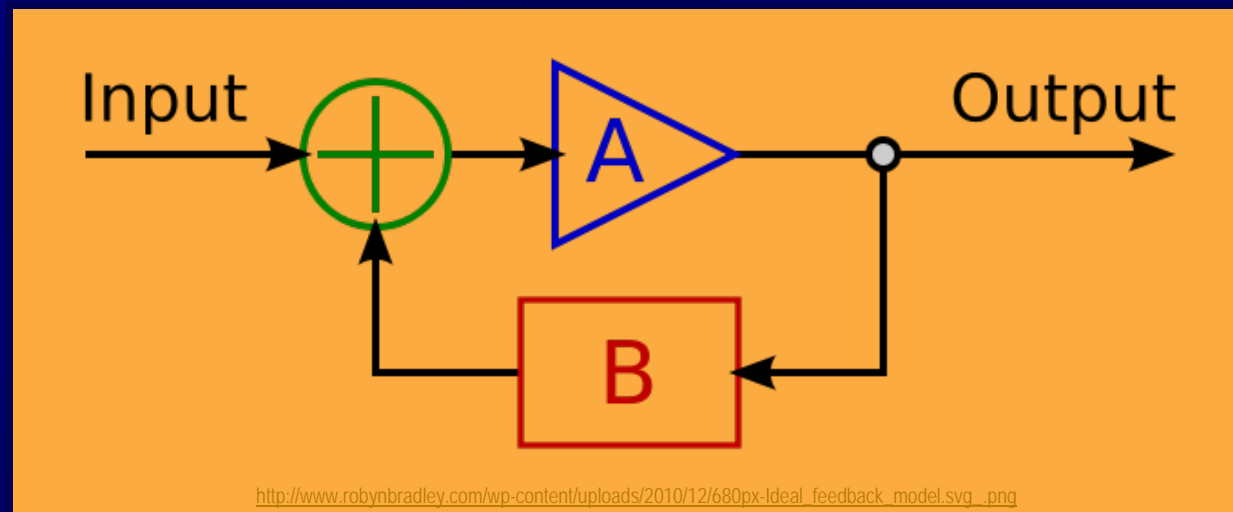
- ✱ System structure often appears without explicit pressure or involvement from outside the system.
- ✱ The organization can evolve in either time or space, maintain a stable form or show transient phenomena.





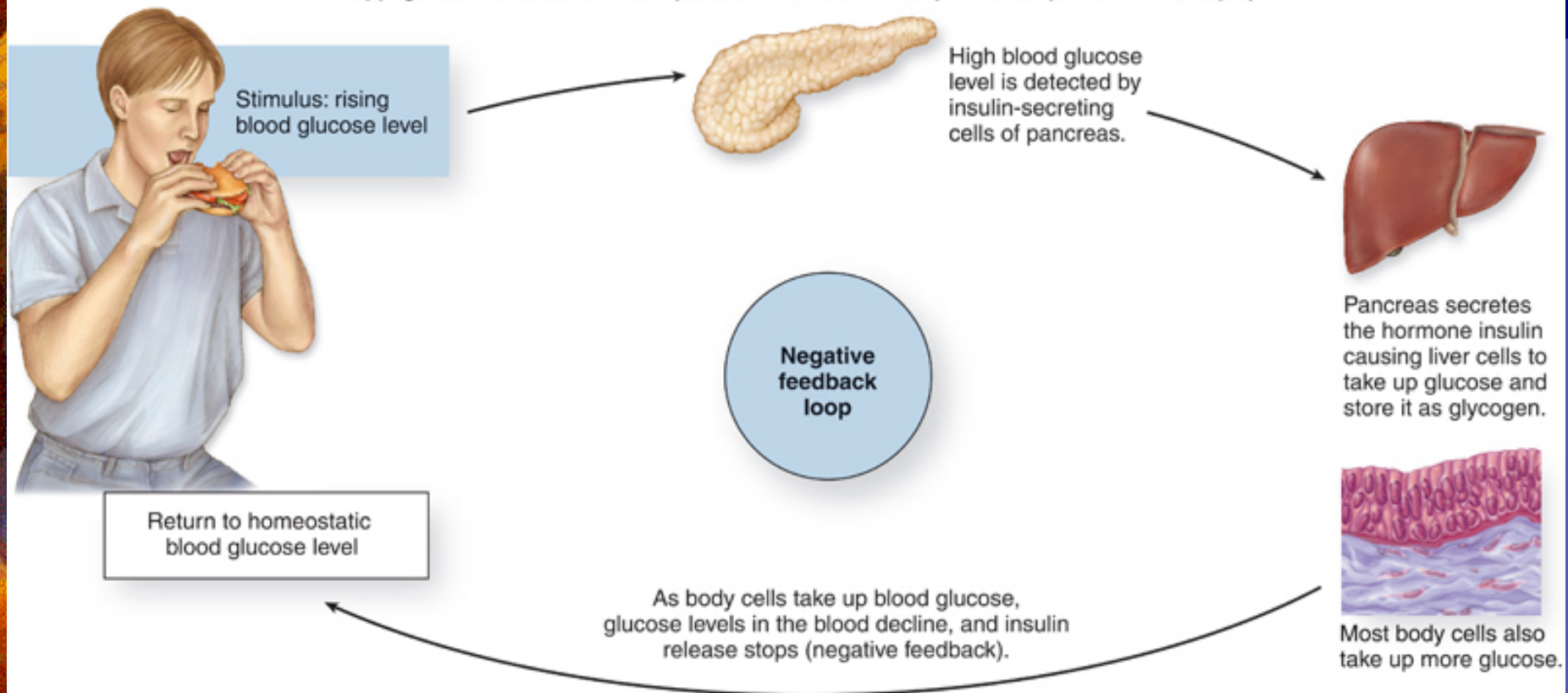
# What are **feedback mechanisms** and what does this have to do with **Life**?

- ☀ There is *feedback* in *chaotic systems* just like in Life because the *outputs* of a *system* affects the *inputs* thus altering it's operation.



# Living things have *negative feedback*. WHY?

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(a) Negative feedback



So how exactly does Life  
depend on chaos?

# Entropy and Chaos

ENTROPY

- ☀ All of the energy in the Universe is being used and most of it (90%) becomes heat after each trophic level or after being given off from a source like the sun or your bodies.
- ☀ Heat dissipates into the Universe and cannot be used again by living things.
- ☀ Thus, **entropy** is energy flowing “downward” toward chaos.

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# Chaos and Negentropy

- ✱ If you were to imagine **entropy** and **chaos** like a water fall of lost heat energy heading toward absolute disorder, there are some matter structures that are able to “fight” its way upwards and use the downward flow to concentrate itself and organize itself into something.
- ✱ This something we call **Life**.





# Life *is* negentropy at the edge of chaos

## *NEW DEFINITION OF LIFE:*

- ★ Thus, Life is the spontaneous creation of ME at the edges of the downward current of chaos forming complex structures that are far from equilibrium and highly dissipative.

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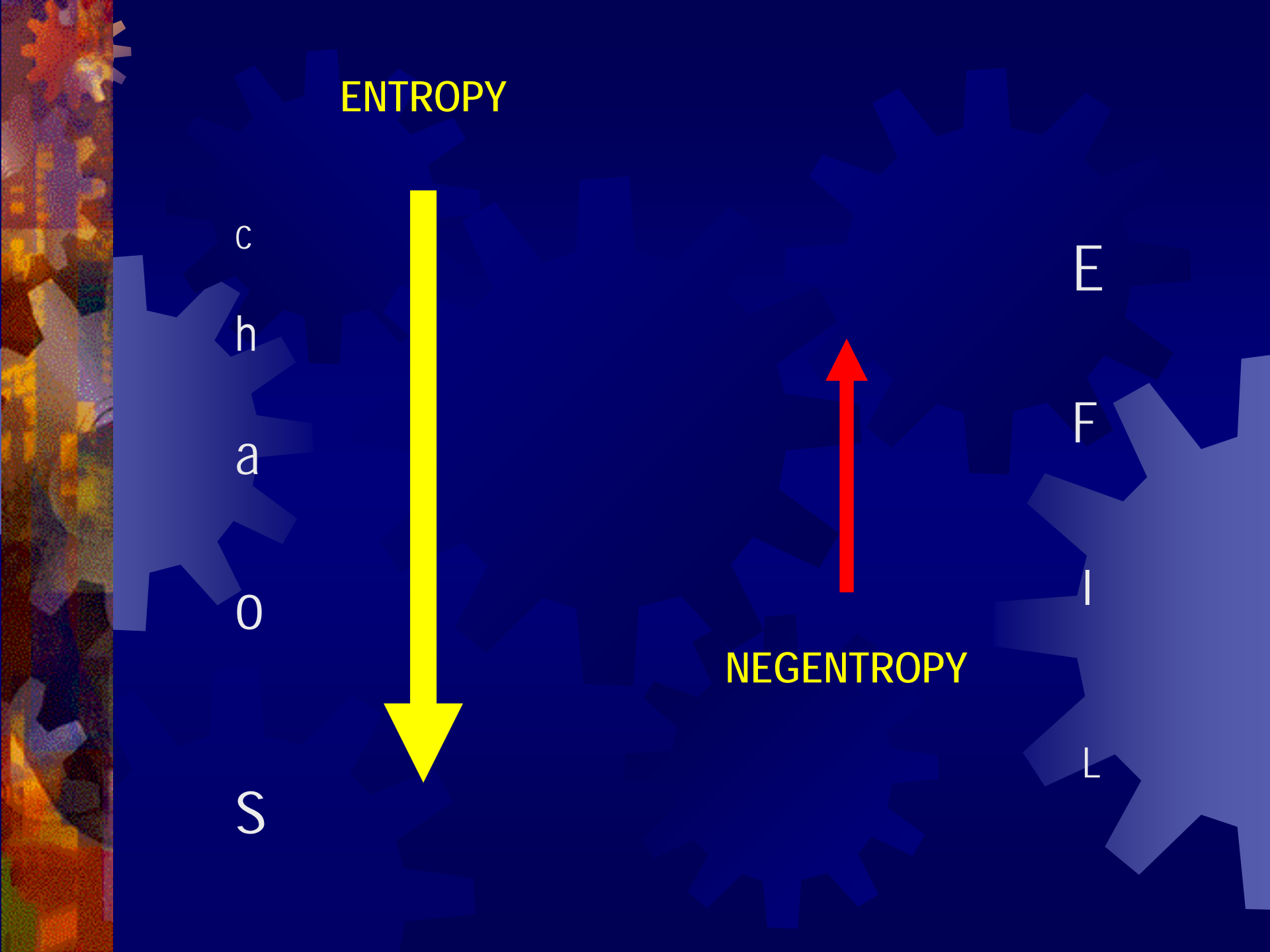
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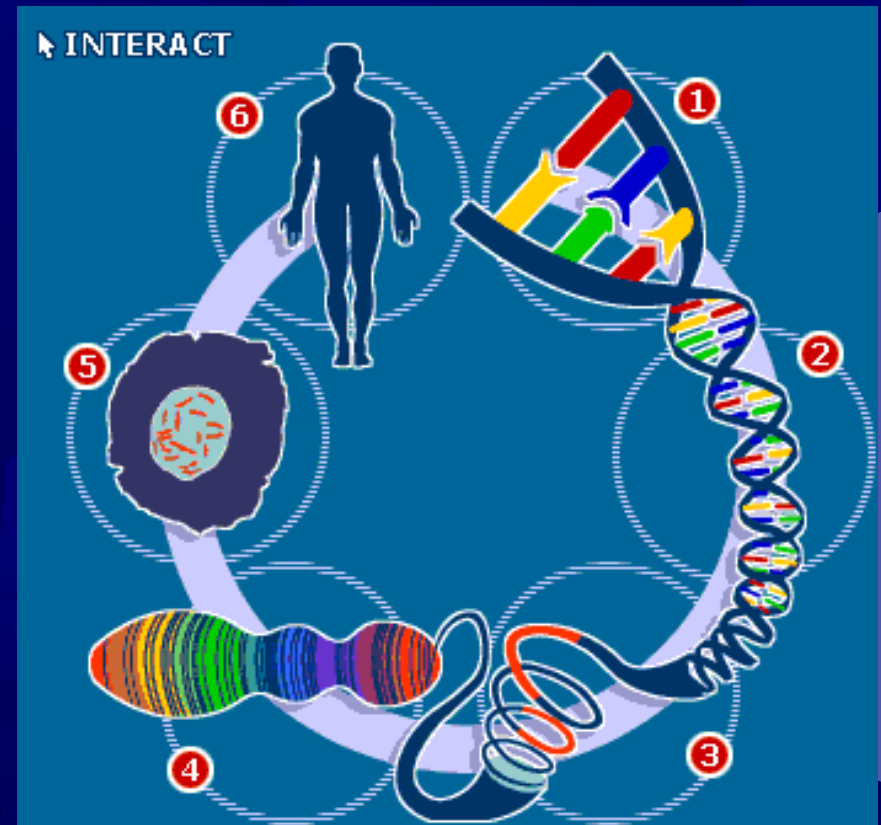
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NEGENTROPY



# How does Life exist at the edge of chaos?

- ★ **DNA** has the information to take advantage of this flow and weave the matter that goes into your body using this flow of energy to **chaos**.



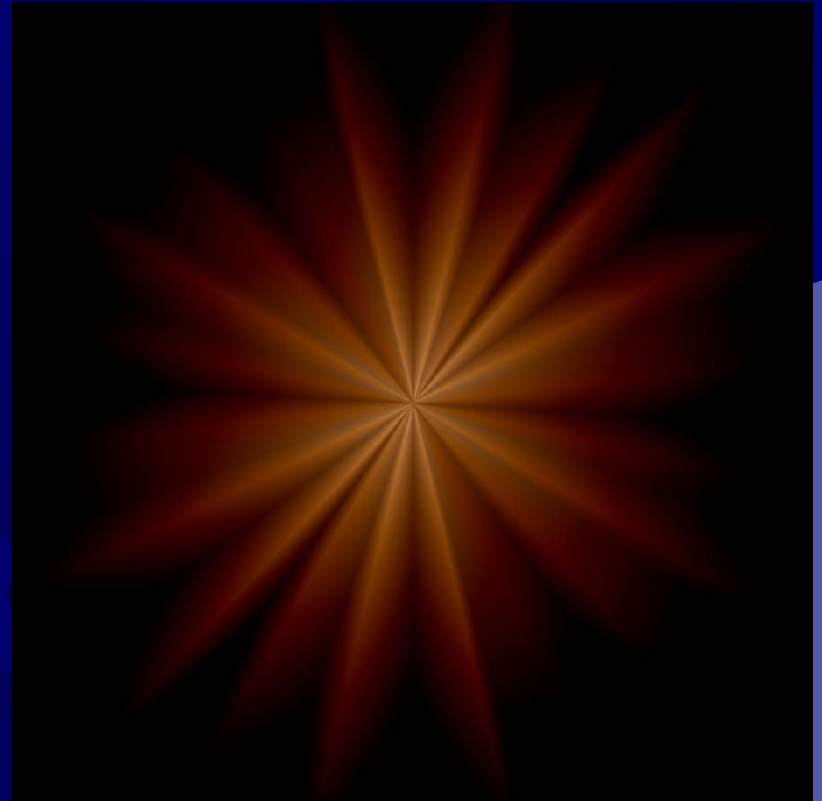
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# OPPOSITES

- ✱ One can conclude that chaos and Life are opposites.
- ✱ But because Chaos exists Life can organize itself and exist.
- ✱ So, what came in the beginning before chaos?

A. **Big Bang** Theory: Then there was an explosion and the universe began to expand.

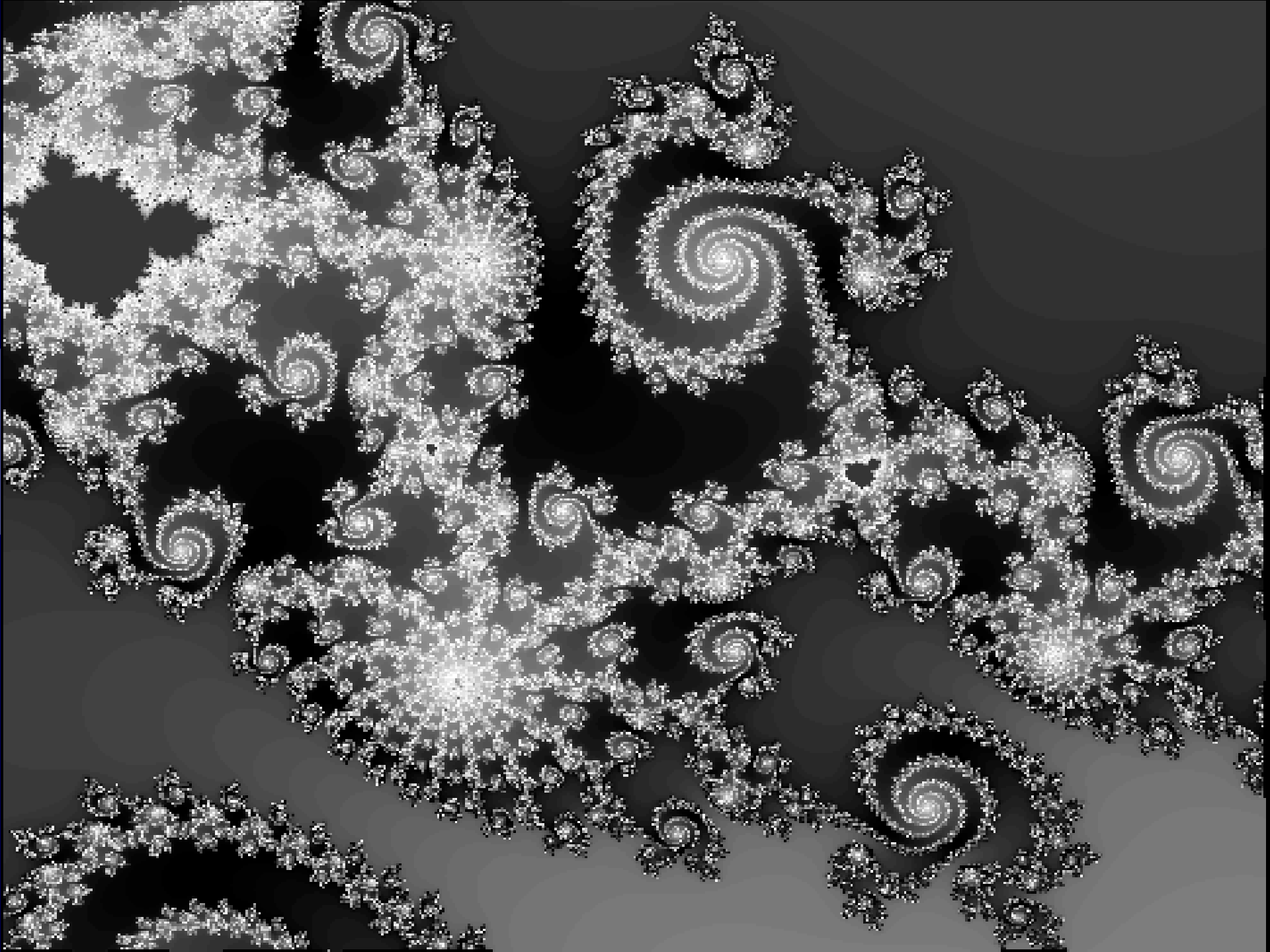
- ✴ The explosion called the Big Bang was the ultimate form of organized matter and energy.
- ✴ And we are back to the beginning of class!

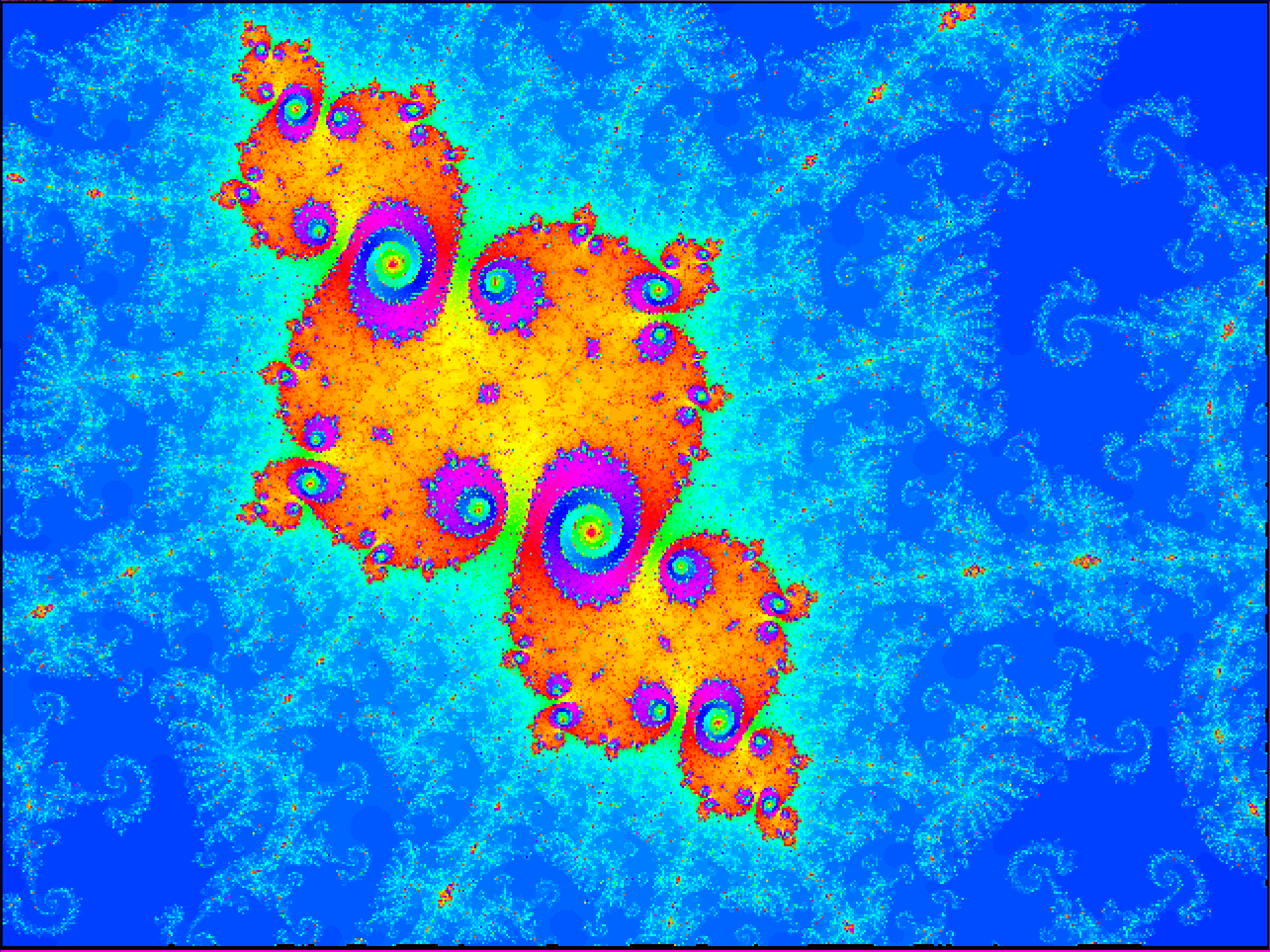


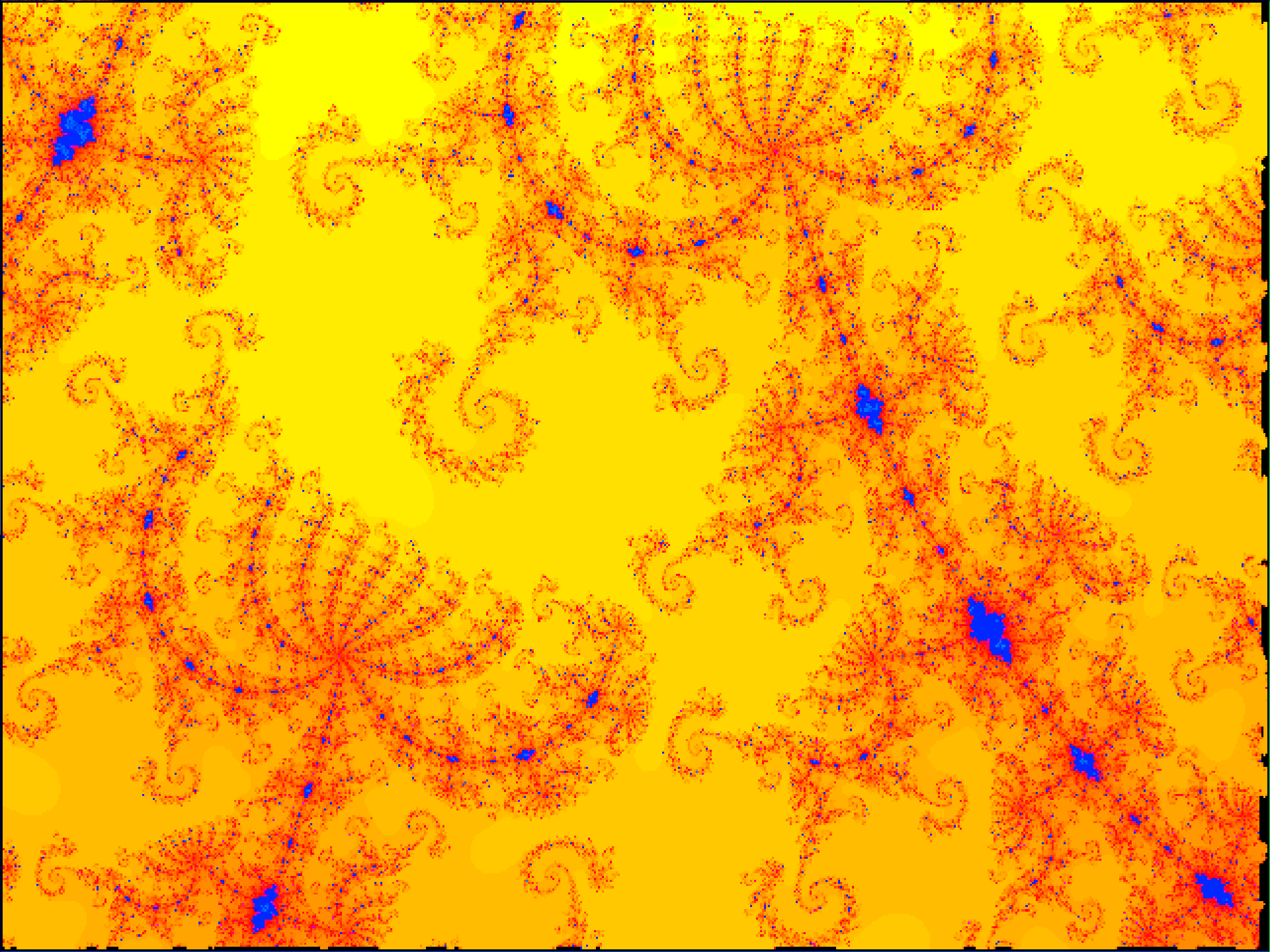


# What can fractals tell us about Life?

- ✱ Fractal geometry is the geometry of special types of irregular shapes.
- ✱ When studied closely, fractals show very highly organized patterns at the edges.
- ✱ These patterns are self organizing, rely on feedback, are highly dissipative, and complex. They are very similar to the idea of Life that we just defined.







# Log activity

- ✱ Compare and contrast the text book definition with the new definition of Life.
- ✱ Describe multiple characteristics of Life.
- ✱ Explain how Life emerges from chaos.





# FIN

Bibliography available upon request.