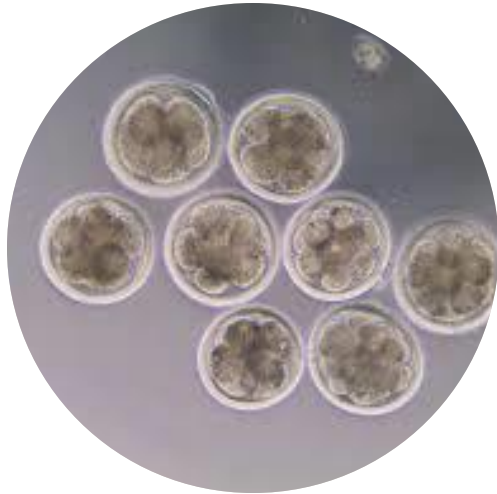


Complex Systems – Emergent Opportunities

Symposium 19 October 2023

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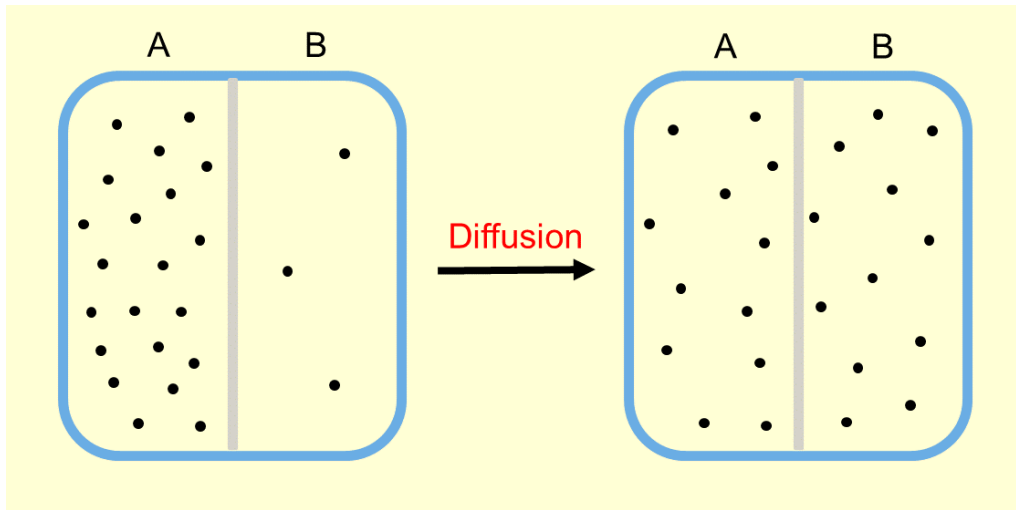
Complexity arose during the evolution of the universe.

What was the driving force?

Energy

Energy quanta tend to flow from where there is a lot, to where there is less.

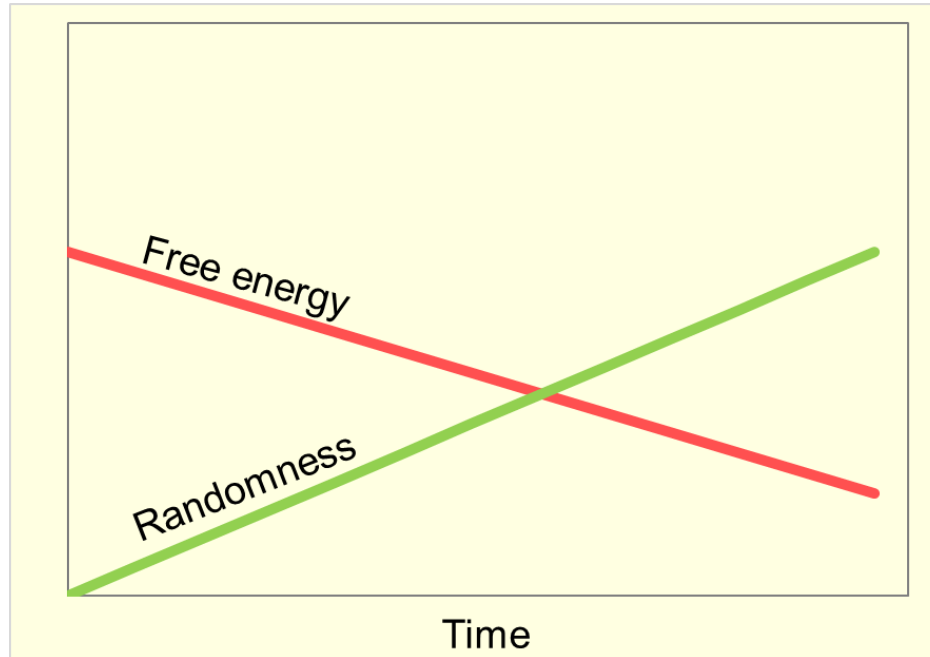
Compare it to diffusion of particles



- Total energy has not changed
- Energy difference is dissipated
- No more ability to perform work
- Less “Free energy”

Allways a decrease of free energy

In all physical processes and chemical reactions



A very simple Universe

1 point



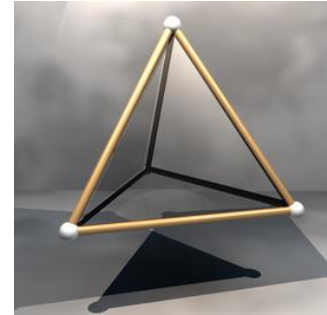
2 points



3 points

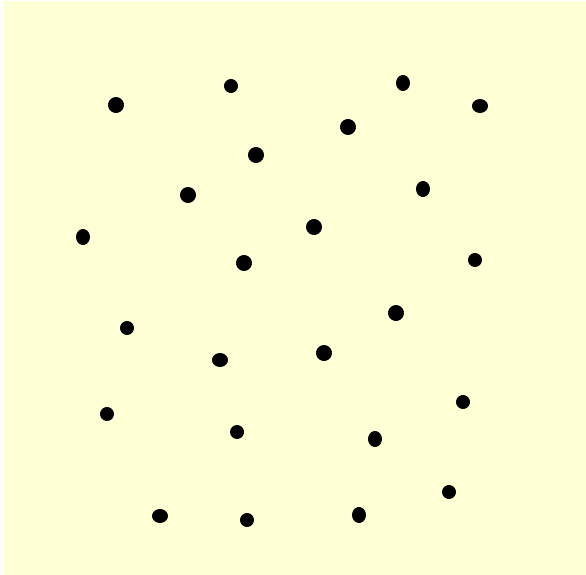


4 points

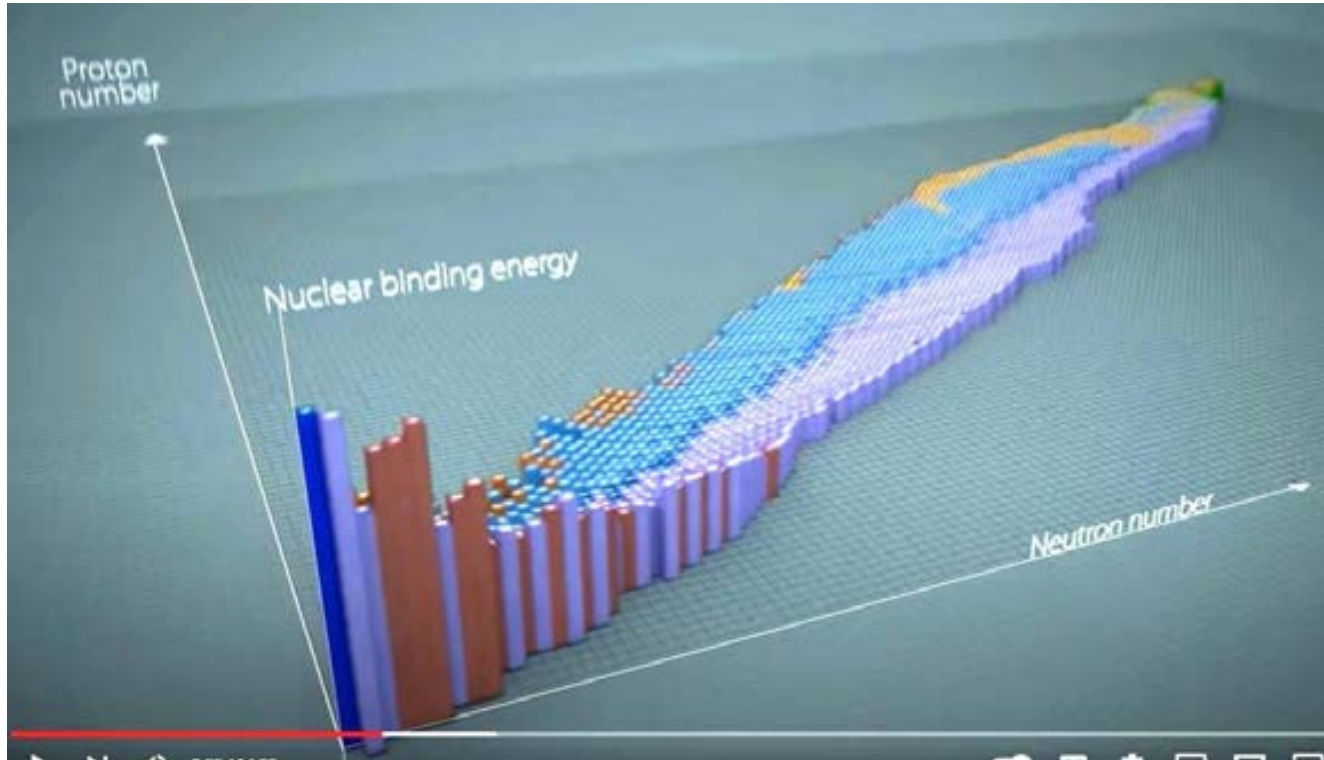


The total is more than the sum of parts:
Emergent properties

A very simple Universe, Only hydrogen atoms

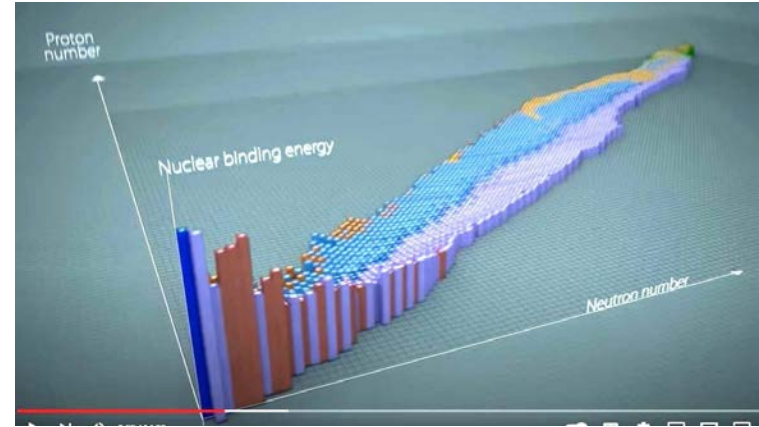


Nucleosynthesis. All elements are formed



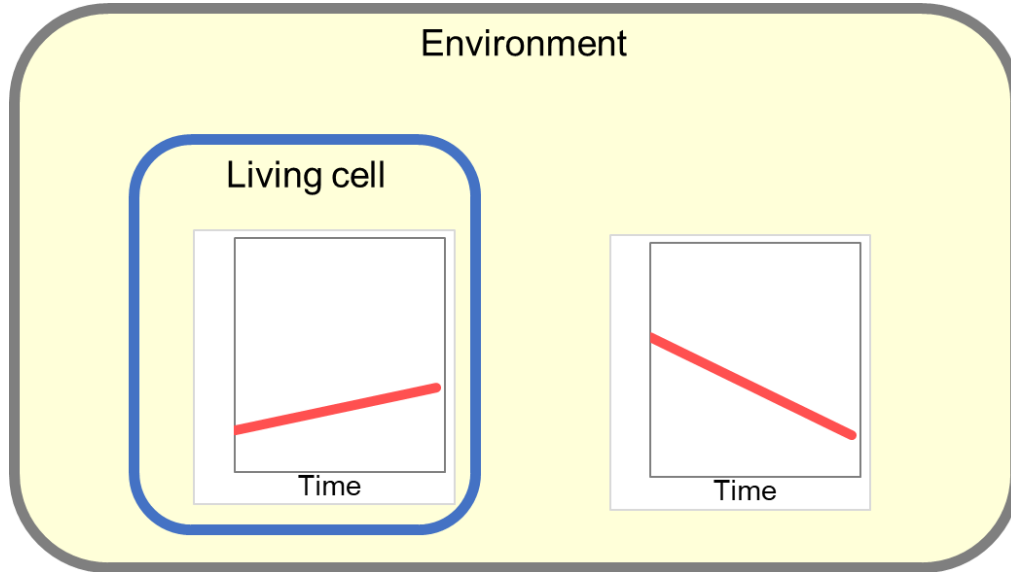
All elements are formed

1	2																	3						
H	He																	He						
Hydrogen	Helium																	Helium						
3	4																	4						
Li	Be																	Be						
Lithium	Beryllium																	Beryllium						
5	6	7	8	9	10																	10		
Na	Mg	B	C	N	O	F	Ne																	Ne
Sodium	Magnesium	Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon																	Neon
11	12	13	14	15	16	17	18																	18
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr							
Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton							
19	20			21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36					
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe							
Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon							
37	38			39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54					
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn							
Cesium	Barium	Lanthanum	Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon							
55	56			57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72					
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og							
Francium	Radium	Actinium	Rutherfordium	Dubnium	Seaborgium	Berkelium	Hassium	Mendelevium	Darmstadtium	Roentgenium	Copernicium	Nihonium	Flerovium	Moscovium	Livermorium	Tennesseum	Oganesson							
87	88			89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104					
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu								
			Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium								
			105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121					
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr								
			Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lanthanum								



- 118 elements, all with new emergent properties
- New, i.e. more possibilities of matter to interact.
- Elements can be combined to myriads of chemical compounds
- Layers of complexity stacked on top of each other

Living matter (1)



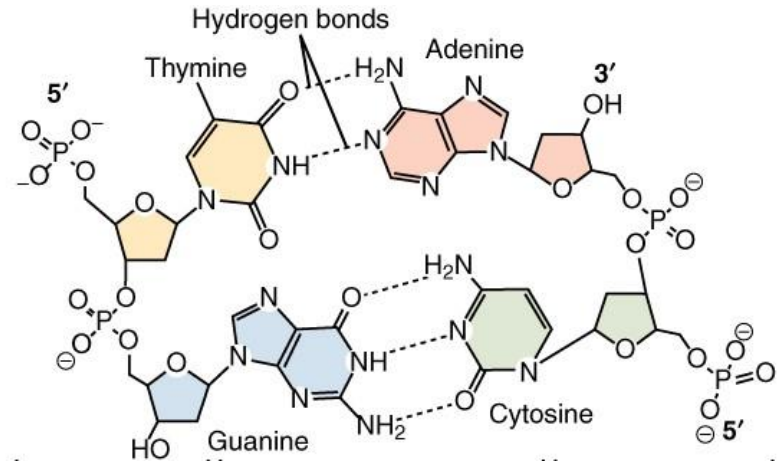
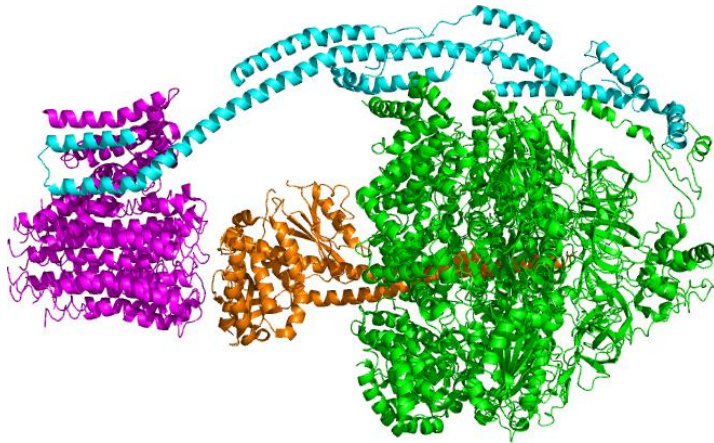
Takes in free energy
from the environment

Exports randomness

Overall, free energy decreases

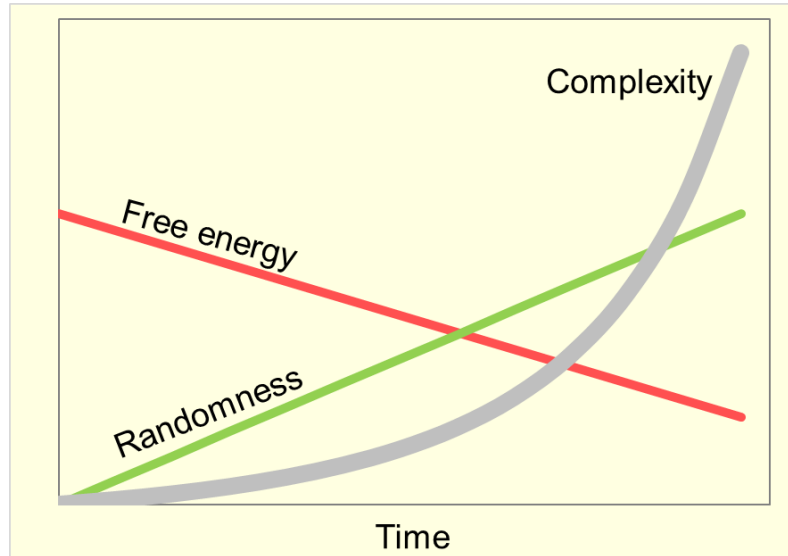
Living matter (2)

- Living matter can maintain and expand (growth) its own ordered state at the expense of decreased order of the matter around them.
- More complicated molecules; New emergent properties



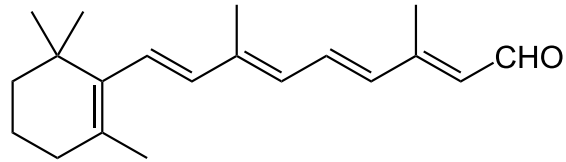
Reiterating

- Everything is driven by dissipation of free energy.
 - All things that happen with existing forms of matter.
 - Creation of new forms of matter: Stars, planets, elements, molecules, and life.



New emergent properties → New opportunities

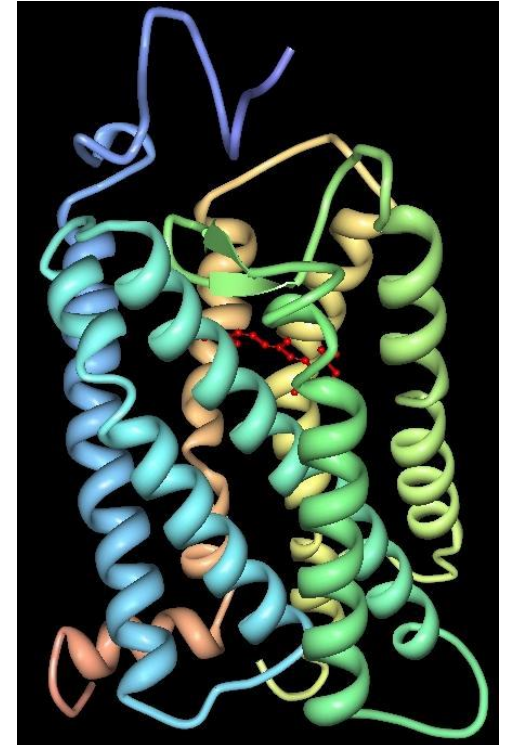
Retinal



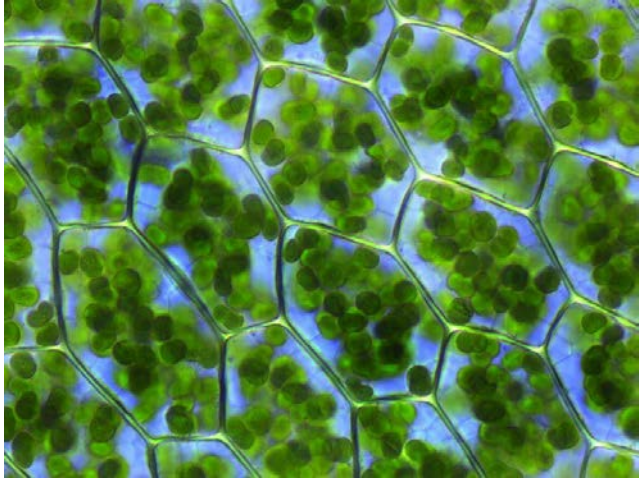
Emergent properties: 'seeing' and photosynthesis.

Rhodopsin: In our eyes and in ancient halobacteria.

Rhodopsin



Higher level combinations → More emergent properties



Chloroplasts are cyanobacteria.
Mitochondria are endosymbiotic
proteobacteria.

Endosymbiosis in early nucleated cells.

Other combinations:

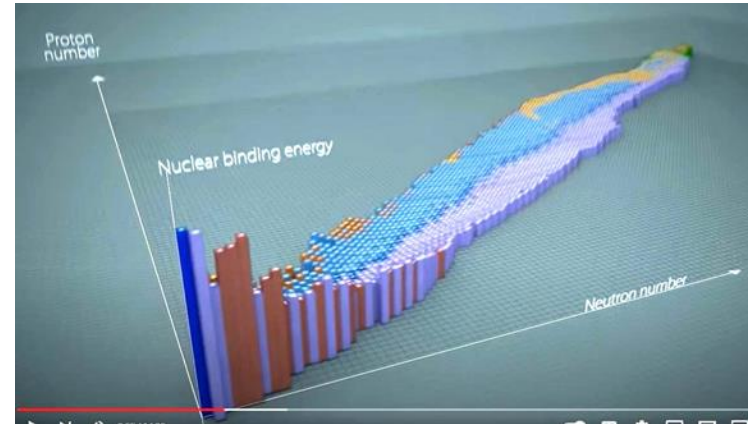
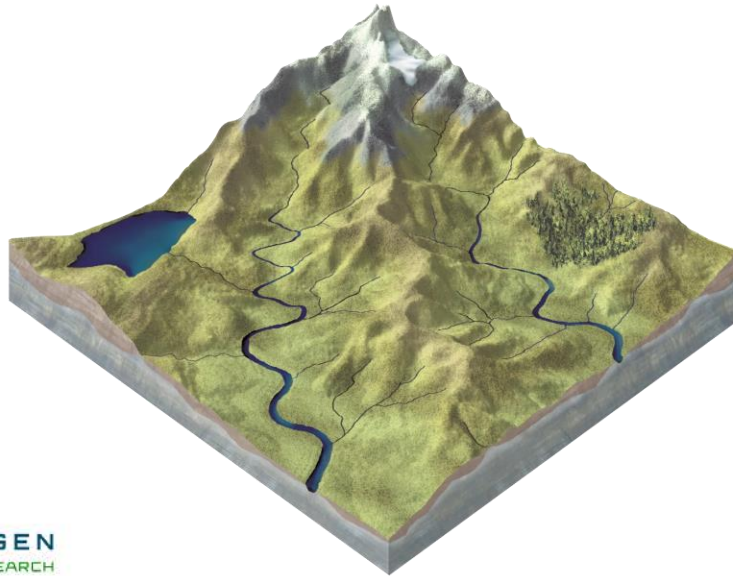
- Multicellular organisms, tissues, organs.
- Societies, symbiosis, ecosystems

New possibilities, new opportunities!

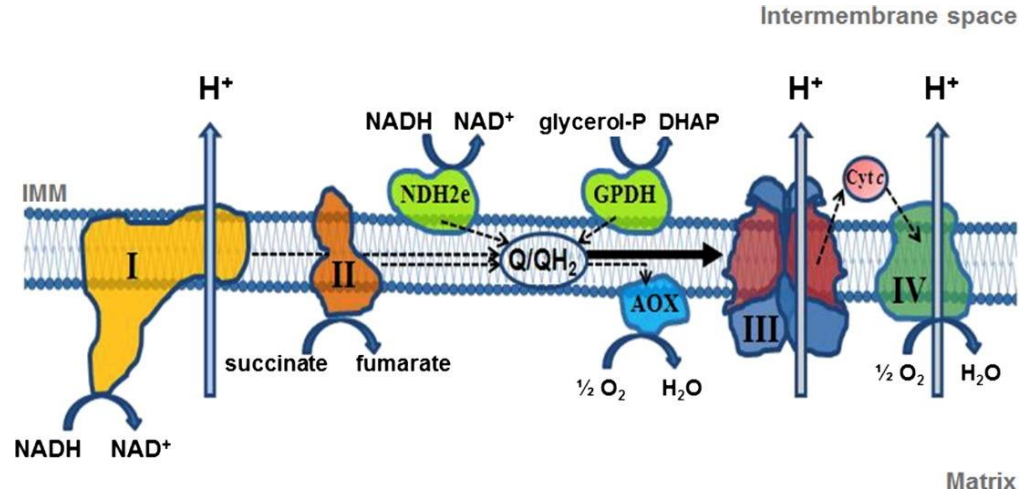
Riverbeds; Pathways for energy

Flow of water is a downhill process, but it follows the shape of the valleys.

The shape and characteristics of matter in the universe provide pathways for the guided dissipation of free energy.

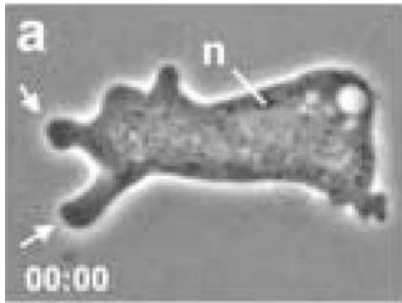


Guided (and useful) dissipation of free energy



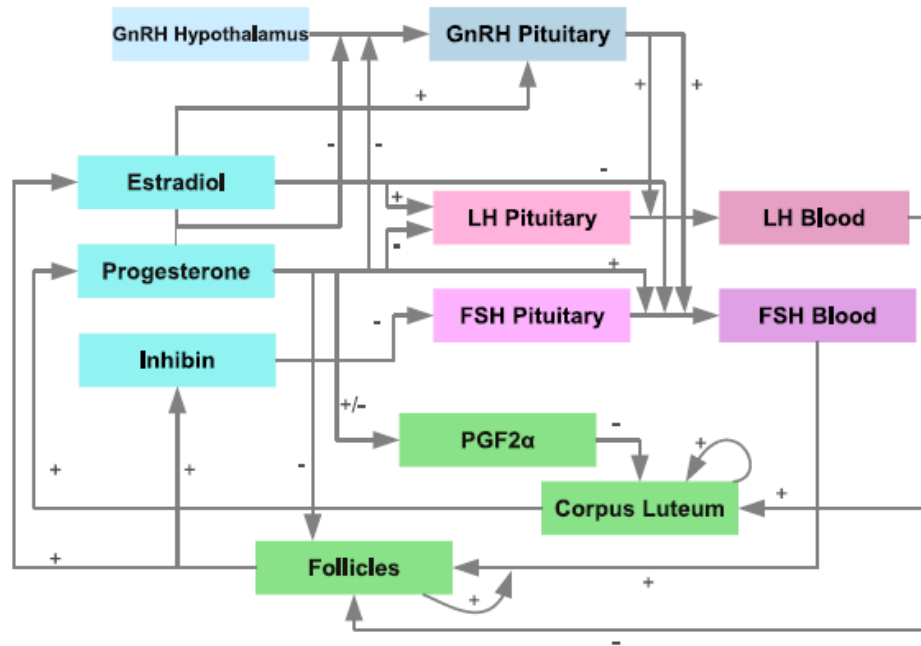
Analogue computers

- Amoebae (and our immune cells) can smell.
- Bacteria too.

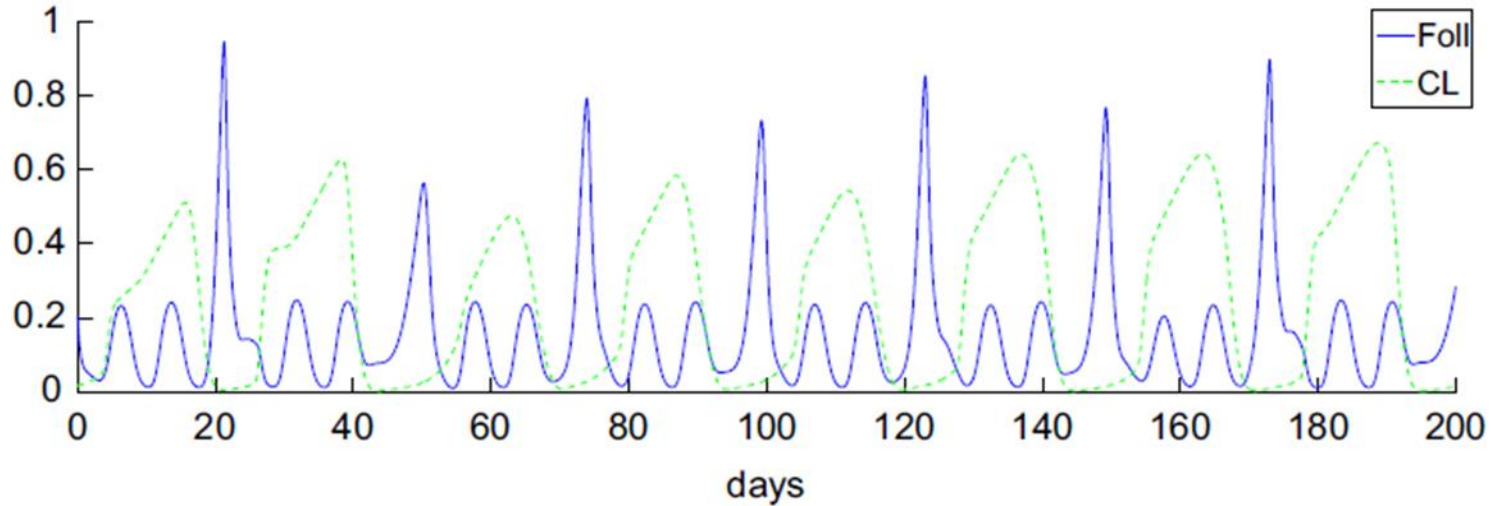
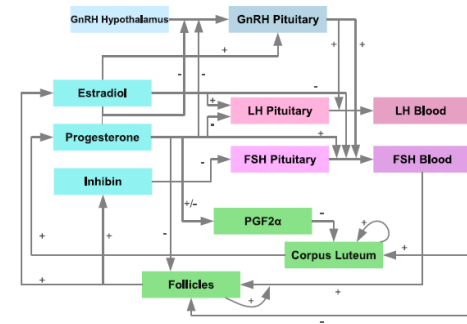


Control systems in our body: Analogue computing

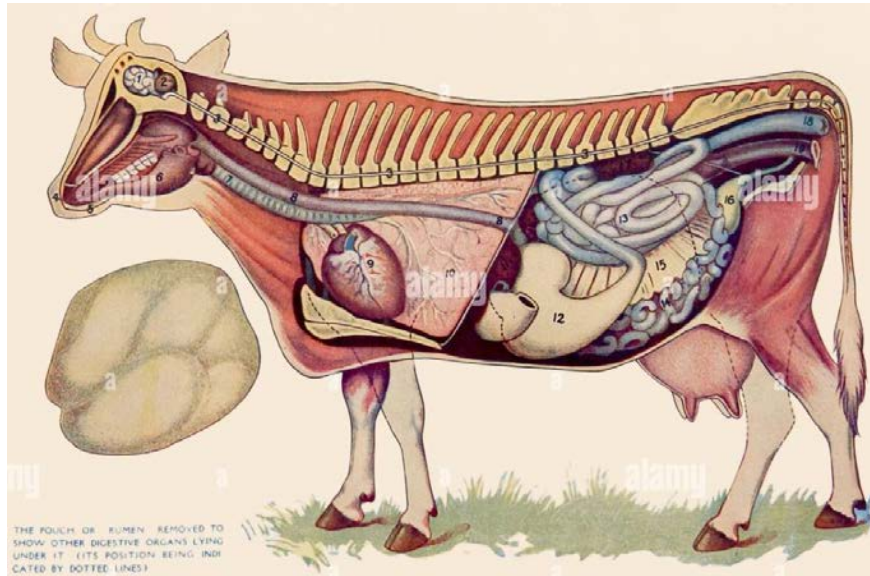
Control systems in our body compute signals in feedback and feed forward loops.



Oestrous cycle of cows



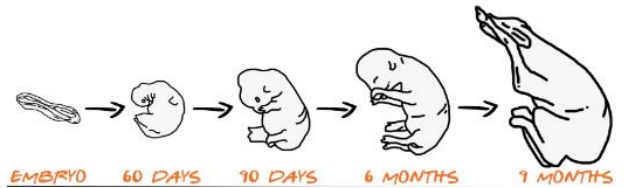
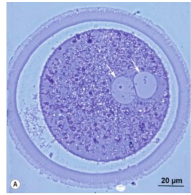
Control systems in our body: Analog computing



- Blood sugar
- Blood pressure
- Body temperature
- Feeding, hunger, thirst
- Response to environment
- Behaviour
- Immune response
- Wound repair

- Etc., etc.

Control systems cannot be constant over time



gametes → zygote → embryo → foetus → newborn → pubertal → adult

The genome in the zygote contains all information needed for that zygote to function as it does, but also contains already all information needed for all successive stages of the life cycle to function as they do.

Epigenetics

But all needed and well-timed/well orchestrated epigenetic changes are also already pre-programmed in the genome of the zygote.

Thought experiment: A 'synthetic' zygote

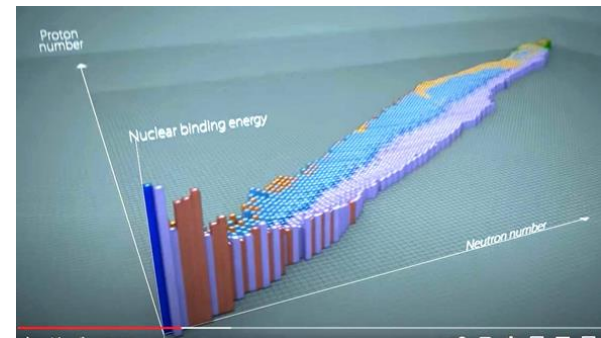
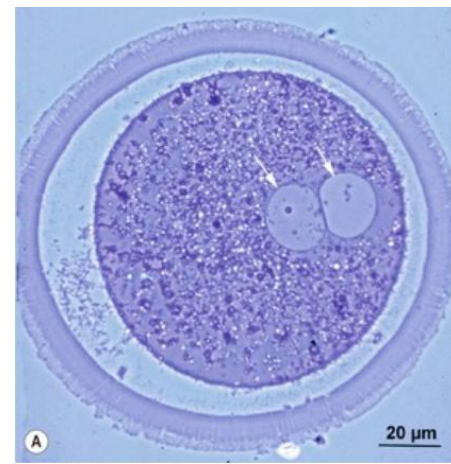
Synthetic biology: Make a cow zygote exactly identical to a real zygote, in full atomic and subatomic detail.

Culture in a culture dish → transfer to a surrogate cow

→ Ultimately gives a newborn calf.

So, this molecular machine, this bundle of matter, can do that! It has this intrinsic property.

Predestination



The mind-boggling complexity

The mind-boggling complexity tempts us to say:

“That is impossible”, “It’s a miracle”.

But then, Woelders’ law says

There are no things that are impossible

Even if we do not understand how.

No ‘miracle’, no ‘intelligent design’.

The fact that we do not understand things exactly is because the emergent property *human intelligence* is not yet a match for the exponential increase of complexity of layers and layers of complexity stacked on top of each other.

The future

The above also means there is still a lot to be discovered.

Complex systems have emergent properties → emergent opportunities.

I'd say that continued scientific research is bound to give us new possibilities, which if used wisely, can be applied to the benefit of mankind.

Thank you for
your attention

Free energy, vs. intrinsic energy

