Selected topics in cognitive science and biomodeling. L1. Brains, Minds and Cognition.

Włodzisław Duch

Neurocognitive Laboratory & Dept. of Informatics
Nicolaus Copernicus University

Google: Wlodek Duch

Practical info

- Name: Selected topics in cognitive science and biomodelling
- Code: 0800-OG-COGNIT
- Nicolaus Copernicus University open lectures for graduate/PhD students.
- Time and place: Monday, g. 18:00-20:00,
  Faculty of Physics Building (Grudziądzka 5), A. J. Audytorium (S. 26).
- First meeting 11.10.2021.
- Form: lectures, 15+15 hours.
- Examination: test questions, but a lot of thinking required ...

Instructors:

- Włodzisław Duch (Google: Wlodzislaw Duch) - neuro part.
- WiesławNowak, Department of Biophysics - biophysics part.

What it will be about

Goal: to give you general orientation how brains work.

1. Panorama: brains, molecules, and the need for multilevel phenomics. Biological mechanisms, network neuroscience and behavior.
2. Basic functions of neocortex, various types of memory, molecular and system level view, large-scale brain networks.
3. Perception: transduction of light, air pressure and tactile stimuli to neural impulses and to visual, auditory and tactile experience.
4. Other forms of perceptions: taste, smell, other senses and synesthesia.
5. Learning and memory: neuroplasticity from biological perspective.
6. Information selection and type of attention: intentional, orienting mechanisms, vigilance.
7. Emotions, subcortical structures and biological processes.
8. Consciousness: disorders of consciousness, theories of consciousness.

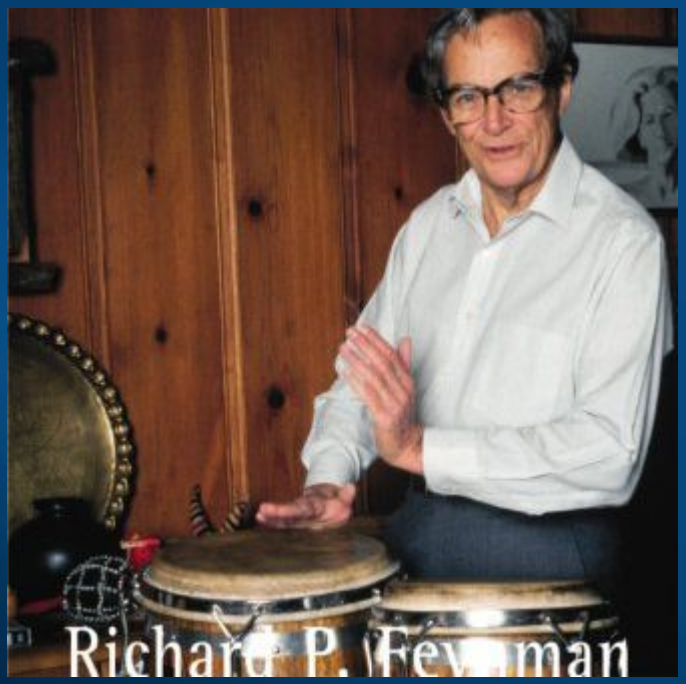
Bibliography

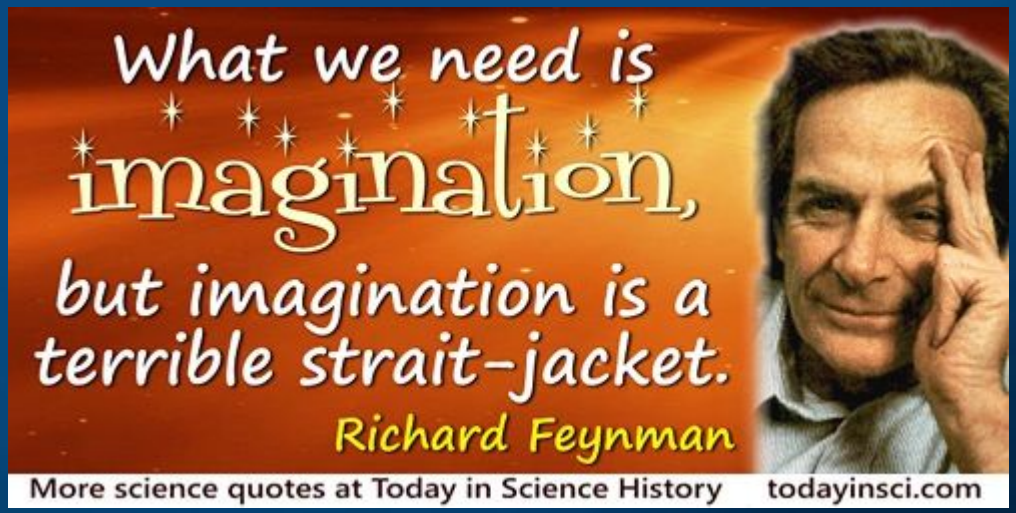
1. Brain Facts, a primer on the brain and nervous system. SfN 2018.
2. Biochemistry, 4th Ed, D. Voet, J.G. Voet, Wiley 2010. (Chap. 1, 4, 5).
3. Protein Actions. Principles and Modeling , I. Bahar, R.J. Jernigan, K.A. Dill, Garland Science 2017.
4. E.R. Kandel et al. Principles of Neural Science, 6th ed, 2021. McGraw-Hill, New York, 1696 pages! Fat book for those who want to know everything.
5. The brain from top to bottom and other Internet sources.
6. Webvision: Retina and Visual System. Covering all things.
7. Neuroanatomy, interactive modules, videos, MRI, crossections …
8. Wiki books: Physiology, Sensory Systems, Consciousness Studies.

9. Fun book: R,M. Sapolsky,
   Behave: The Biology of Humans at Our Best and Worst. Penguin Press 2017

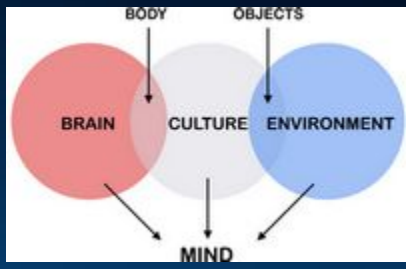
Famous bongo player

Richard P. Feynman, The world looks so different after learning science. What Is Science: The Physics Teacher: Vol 7, No 6 (1969)





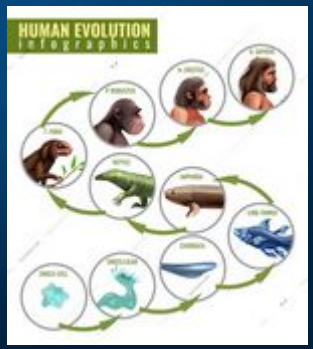
CS 4 Key Questions



"First, you can't begin to understand things like aggression, competition, cooperation, and empathy without biology" (R. Sapolsky. Behave, 2017).

Four key questions for cognitive science and their timescales:

1. How mental states arise from specific activity of the brain networks?
   Millisecond to second scale – neurodynamics.
2. How the state of the brain changes due to interactions with the environment? Minutes to hours – priming, learning, hormones.
3. How brain activity arises from the state of the whole organism?
   Hours to years – neuroplasticity, developmental and aging processes.
4. How has it all came about? Millenia, eras and eons.
   Deep history of ourselves (J. Le Doux) – evolution.



Ad. 1/2. Duch W. (2012) Mind-Brain Relations, Geometric Perspective and Neurophenomenology, American Philosophical Association Newsletter 12(1).

Explanations

Seconds

Minutes

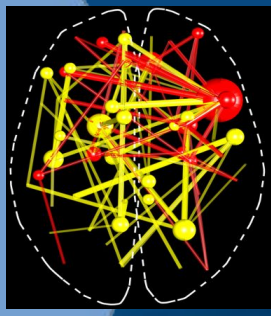
Days

Month

Years

Millenia

Eras/Eons



Cognitive phenomics, fast/slow: neurodynamics, hormones, education, culture, infancy, gestation and evolution.

Mind/brain phenomics

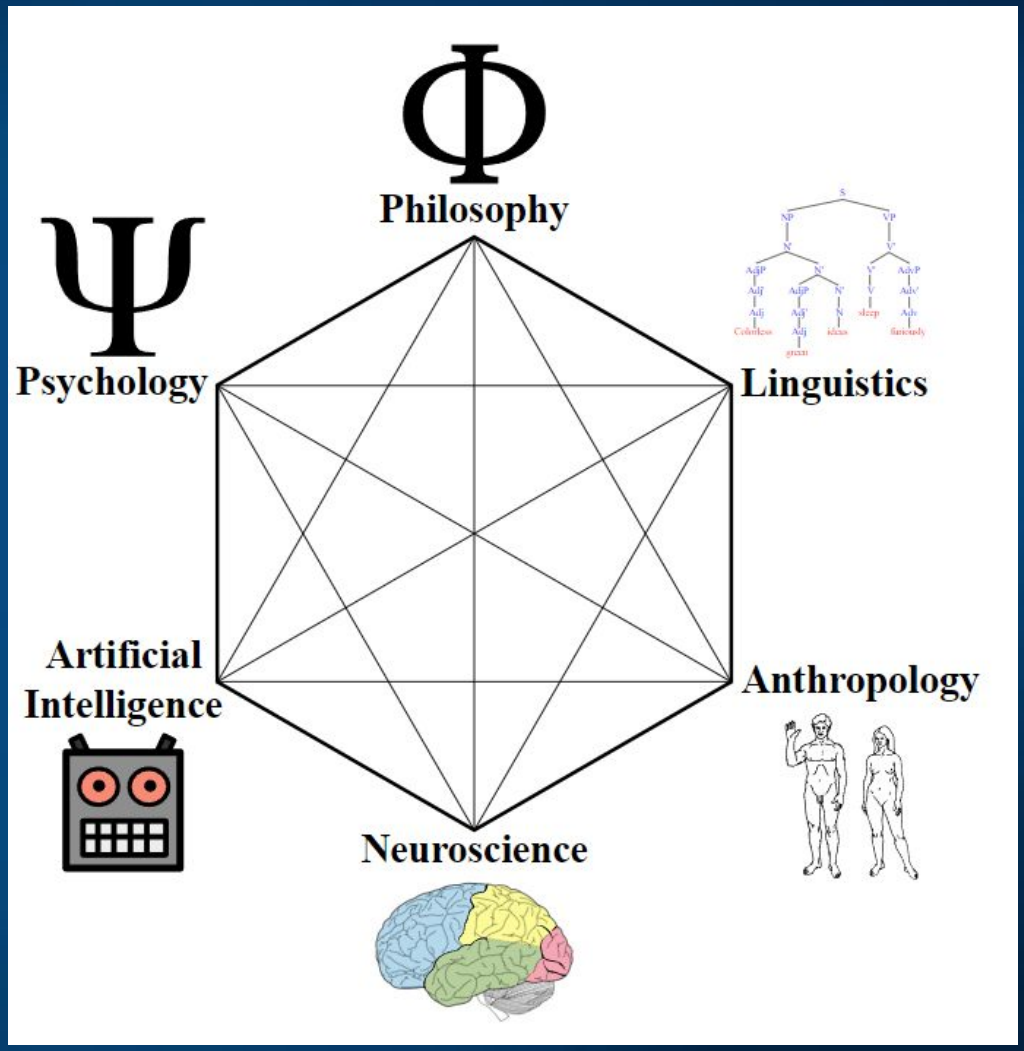
Cognitive Sciences

6 pillars of Cognitive Sciences.

Understanding our behavior and mental states requires integration of knowledge from many different fields.

They have their specificity, but there is a lot of interactions and overlaps between them.

“Neuro” may be added to all branches of science: philosophy, psychology, informatics, linguistics. Anthropology studies human behavior, biology, culture and societies. Neuroscience has molecular and network levels.



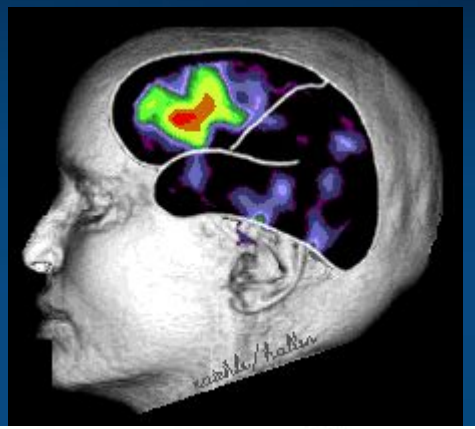
Miller, George A (2003). "The cognitive revolution: a historical perspective". TRENDS in Cognitive Sciences 7

Brains ⇔ Minds

Define mapping S(M)⇔S(B).

Brain-Computer Interfaces: intentions => actions.

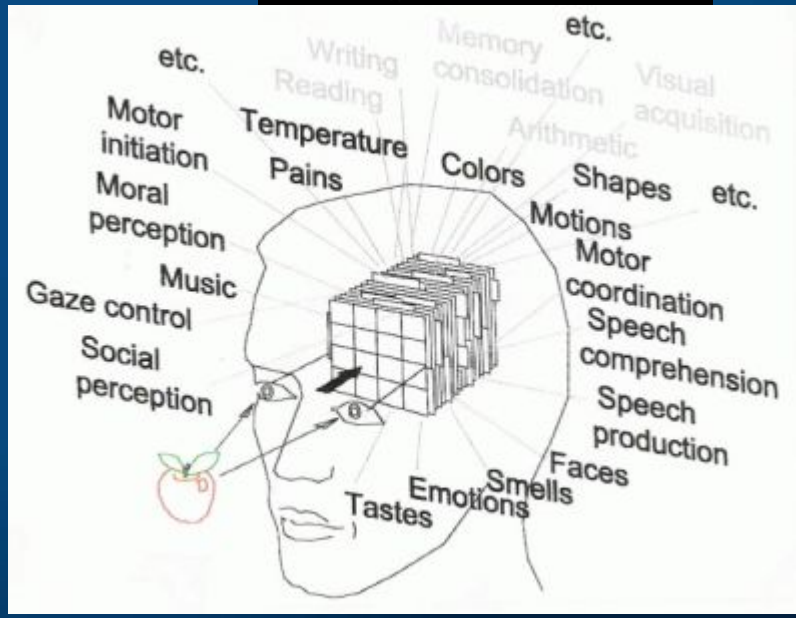
Neurodynamics: bioelectrical activity of the brain, neural activity measured using EEG, MEG, NIRS-OT, PET, fMRI ... Links to mental states are possible.



But … how do we describe the state of mind?

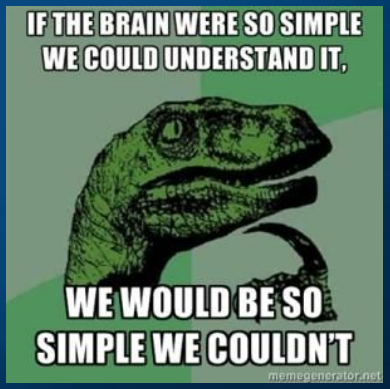
Verbal description should be quantified, words represented in a space with dimensions that measure different aspects of experience.

Dynamic cognition: stream of mental states, movement of thoughts
⇔ trajectories in psychological spaces.



Possible problems

1. Such mapping will at most answer how it works, but not why.
   How did we get to this point?
2. How it works depends on so many factors, we cannot known all of them
   – neither initial conditions, nor all elements and their interactions.
3. Brain states are continuous and rapidly changing.
   Can neurodynamics be explained verbally in a comprehensible way?
4. Are we able to describe our mental states? Try it!
   Introspection has failed as the basis of psychology in XIX century.
   Lack of good phenomenology.
5. Can the brain understand itself? At what level?
6. What does it really mean to understand?
7. Can we define mind, intelligence or consciousness?
8.



E. Schwitzgabel, Perplexities of Consciousness. MIT Press 2011.
A.M. Turing, Computing Machinery and Intelligence. Mind 59, 433-460 (1950)

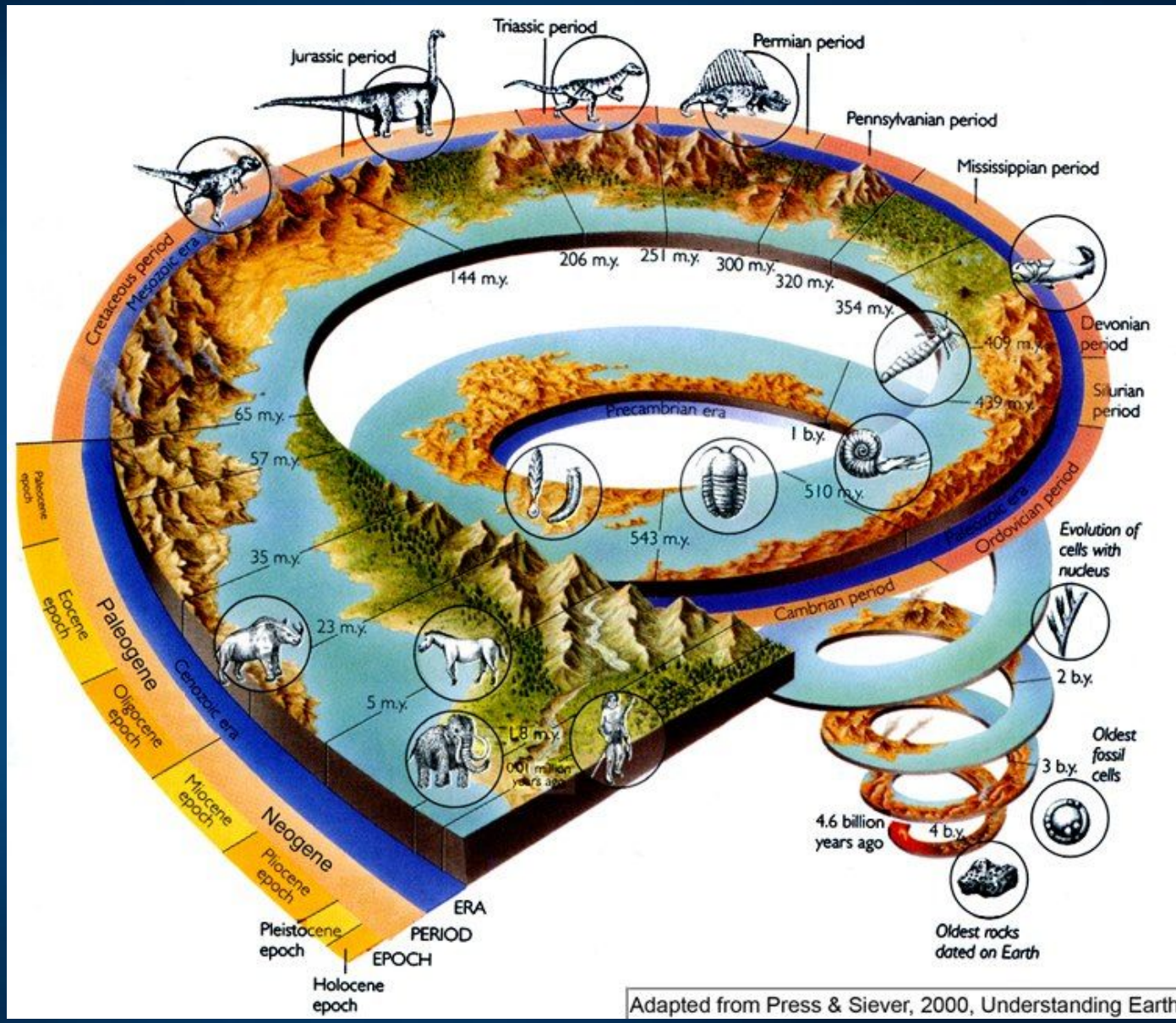
Evolutionary perspective: functions required for survival

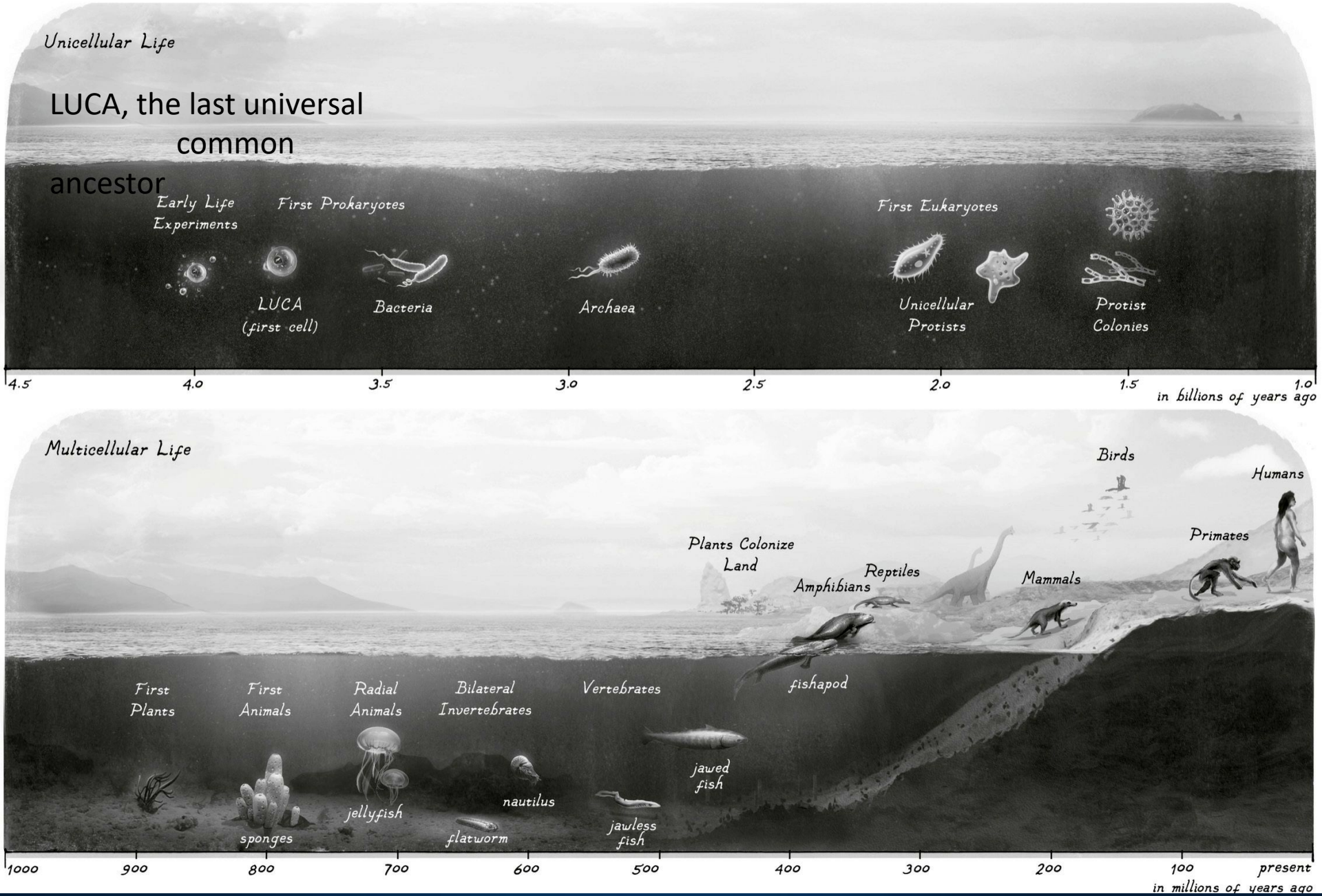
From cells to organisms

Why?
Evolutionary perspective.

D'Arcy Thompson, On Growth and Form (1917). Everything is what it is because it got that way.

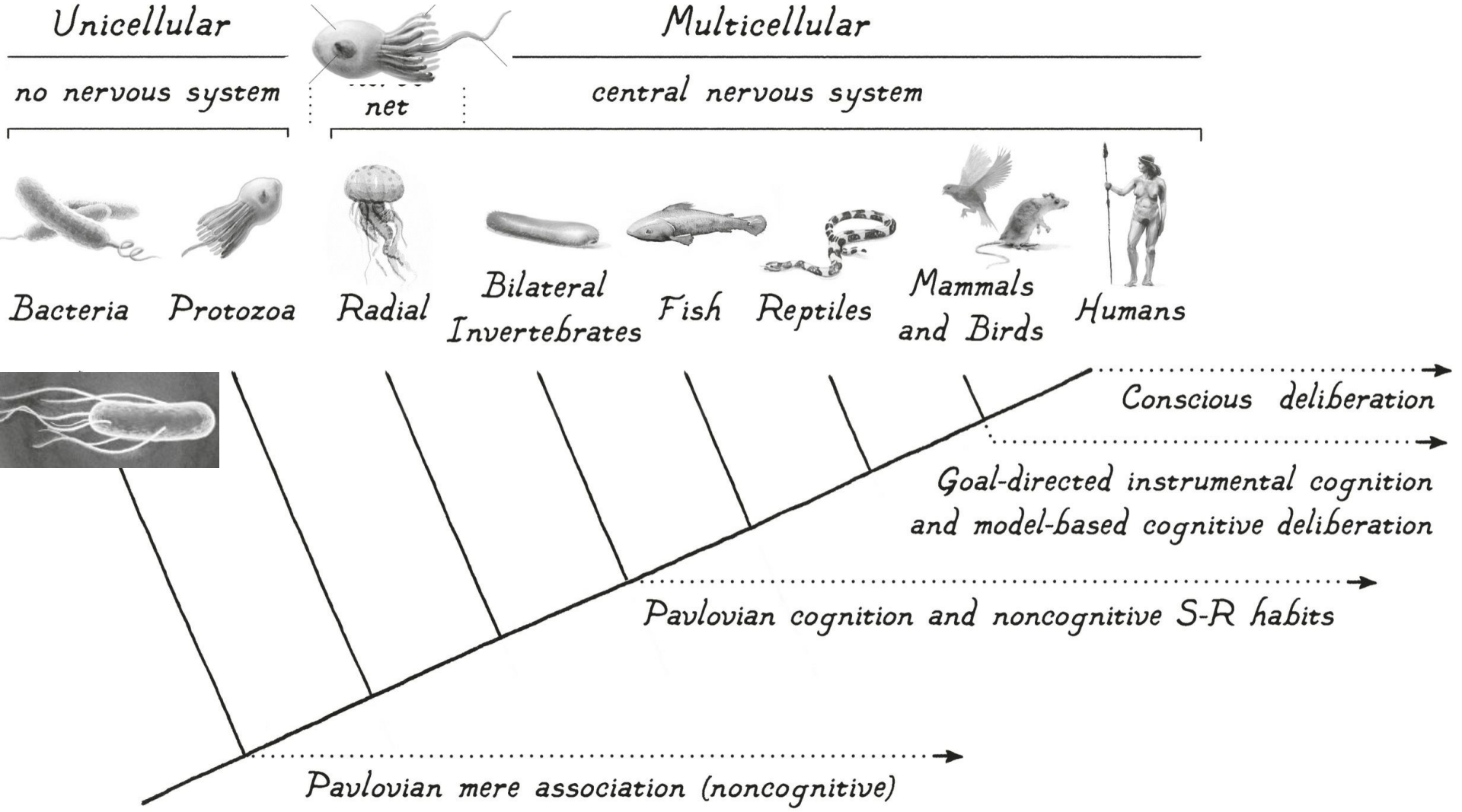
Joseph LeDoux, The Deep History o f Ourselves : The Four-Billion-Year Story of How We Got Conscious Brains. 2019





LUCA, the last universal common ancestor

Bacteria with flagella, protozoa have shorter cilia,
choanoflagellates feed on bacteria, are closest single-cell relatives of animals.



Why do animals need brains?

- Real challenge for robotics: survive in a hostile environment.
- Animals that survived are well adapted for particular ecological niche.

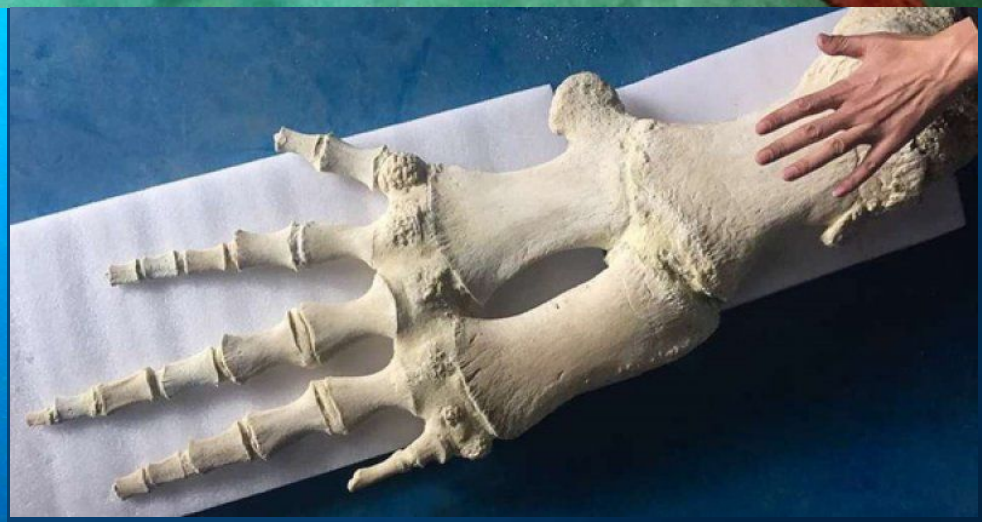
Tunicates (Ascidians, called also sea squirts):

- Larval forms resemble small tadpoles, swim moving a tail, have a simple eye and balancing organ, controlled by a cerebral ganglion (primitive brain).
- Grown form cements itself to a rock, frequently in a large colony.
- Brain is no longer needed and is digested! Tunicates feed by filtering water.

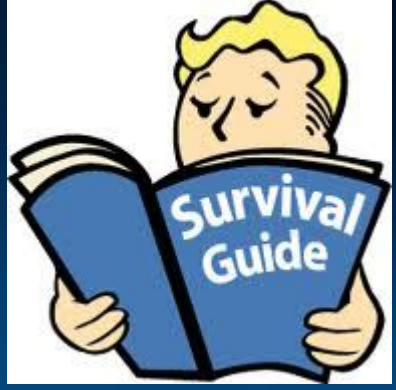
Birds also change their brain in the mating season.

Brain is needed to control movement of large organisms, unicellular organisms also move.

Movement helps to find more nutrients.



To survive requires …



- **Homeostasis** to regulate basic metabolic functions and internal environment, controlling concentration of chemicals derived from nutrients, air, thermal and light energy. Complex organisms need cooperation of endocrine system and autonomous nervous system.
- **Drives**, motivations and instincts to undertake actions that lead to homeostasis, with some reward mechanisms.
- **Sensors/effectors** for fast affective reactions: avoiding dangerous situations, pursuing opportunities for feeding/mating. Requires specialized sensors and attentional systems to discover patterns, associate them with values, and activate motor control system.
- **Basic cognition**: spatial orientation and memory, learning through associations and simple planning, perceptual learning.
- **Complex cognition**: imagery enabling prediction of action results, long-term goals, representation of self, understanding of causal connections.

Orientation: receptors

Unicellular organisms (like Paramecium) move towards chemical gradients of nutrients, bacteria, algae, small cells.

Such organisms may learn by altering biochemical cycles.

Reaction to light is quite useful and photoreceptive proteins were relatively easy to create, ex. eyespot apparatus in green algae that can swim towards or away from light, or snails eyes.

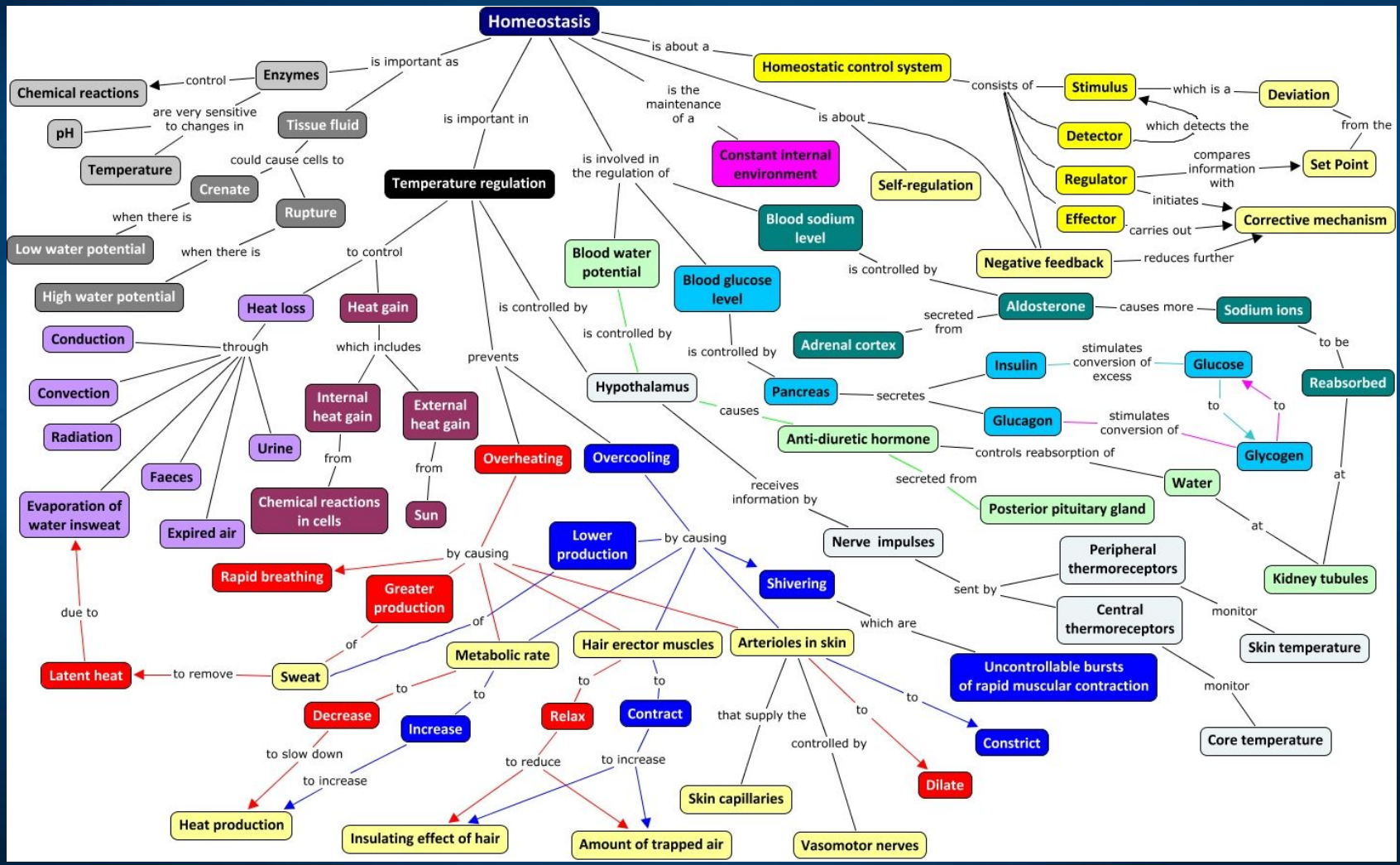
- 10 forms of eyes have evolved from that, based on common genetic mechanisms, with matrices of eyespots,
  to compound eyes of flies and shrimps, to vertebrate eyes
  and more perfect cephalopod (octopus) eyes.

Other useful receptors:

- Chemical sensors, leading to taste, olfaction, thirst and hunger, craving for specific food and substances.
- Mechanical sensors, enabling body orientation and equilibrium, vibration detection, pressure, hearing,

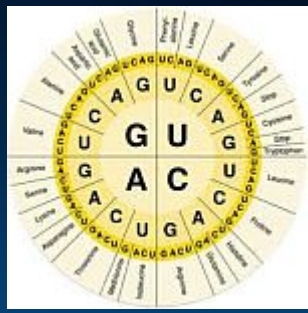
Homeostasis

- What in this map is still missing? And what do we need for robots?



From Homeostasis(ihmc.us)

Evolution rarely looks back



- **Genetic inventions** are preserved in more complex organisms.
- A part of human genome useful in the past, evolved in quite different circumstances, may not be useful or even harmful today: it is called evolutionary baggage.
- During the Ice Age variation in the human leukocyte antigen (HLA) genes lowered the freezing point of the blood by reducing production of insulin, keeping blood sugar levels high: now many Scandinavians who descend from these northern populations suffer from type I diabetes.
- Evolutionary medicine explains how and why bacteria, viruses, microbes, parasites adapt to resist antibiotics, how pathogens learn to cheat the immune system, how organisms evolved to escape from these attacks by inventing sex and evolving faster (see the Red Queen hypothesis).
- Hiccoughs have been connected to the expression of gill ventilation in frogs, originating pattern generators for suckling or regular breathing.
- Freezing behavior: common to many animals (insects) when frightened.
- Left-right crossed connections in the brain is linked to coiling of worms.

Complex behavior

Courtship of the male Maratus speciosus (Coastal peacock spider).
Peacock spider dancing, even house dust mite, not just birds and mammals!