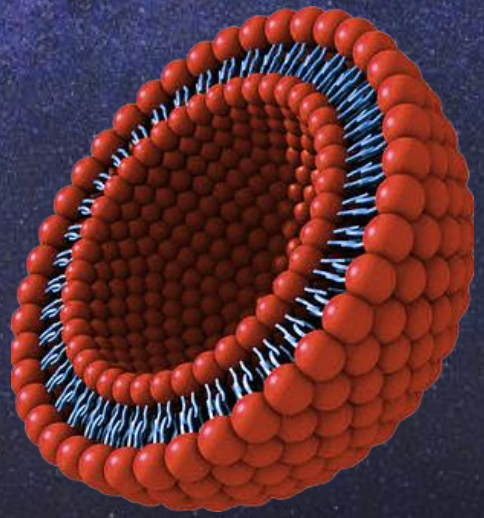
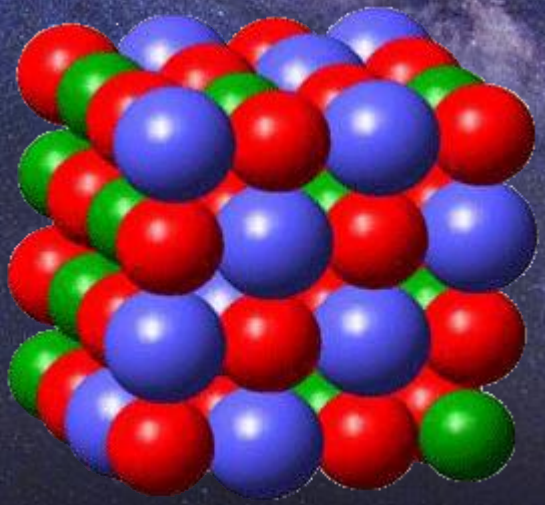
The great basic question of science:

Membrane compartment or non-membrane phase compartment is the physical basis for origin of life?





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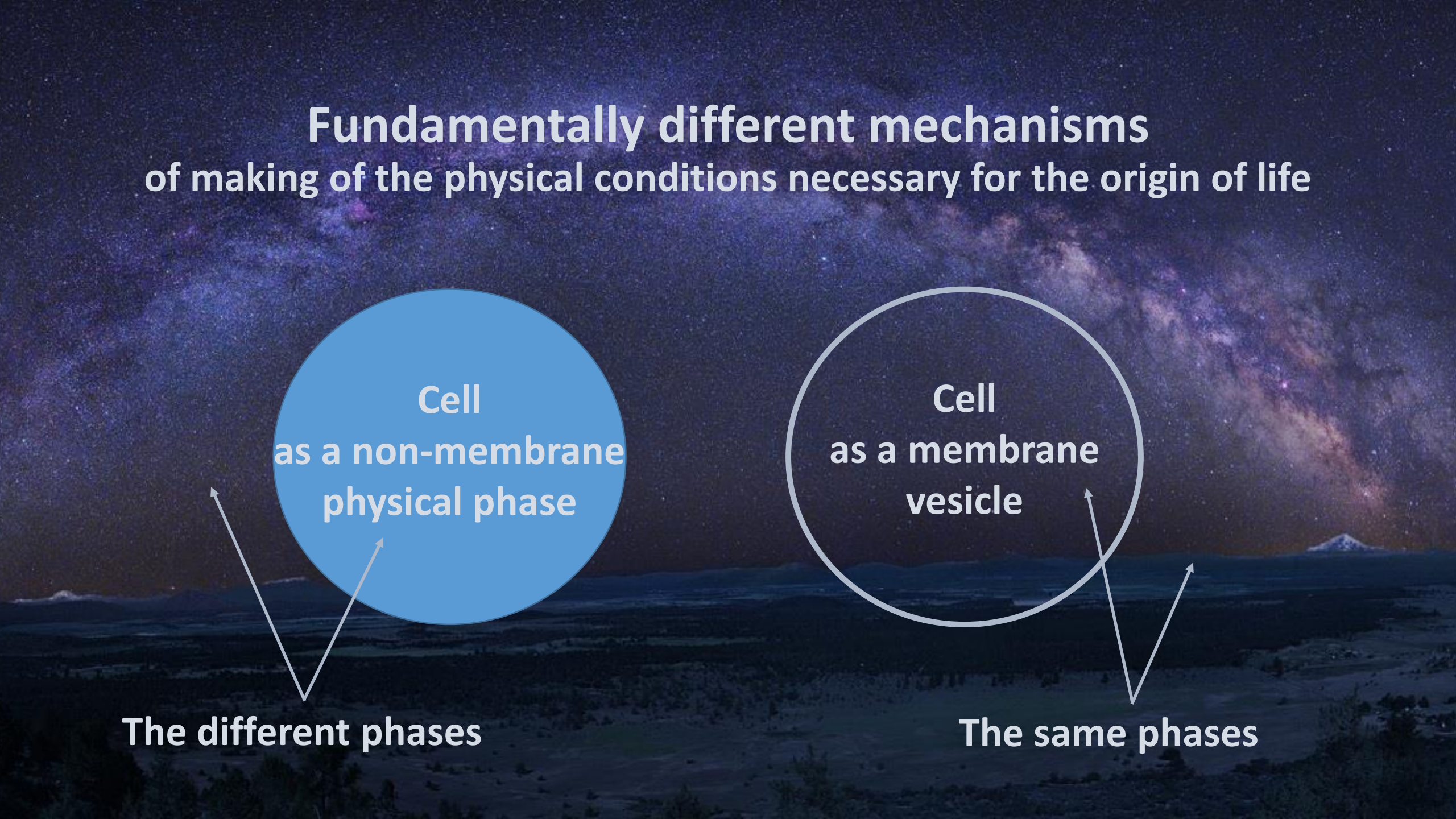
Fundamentally different mechanisms
of making of the physical conditions necessary for the origin of life

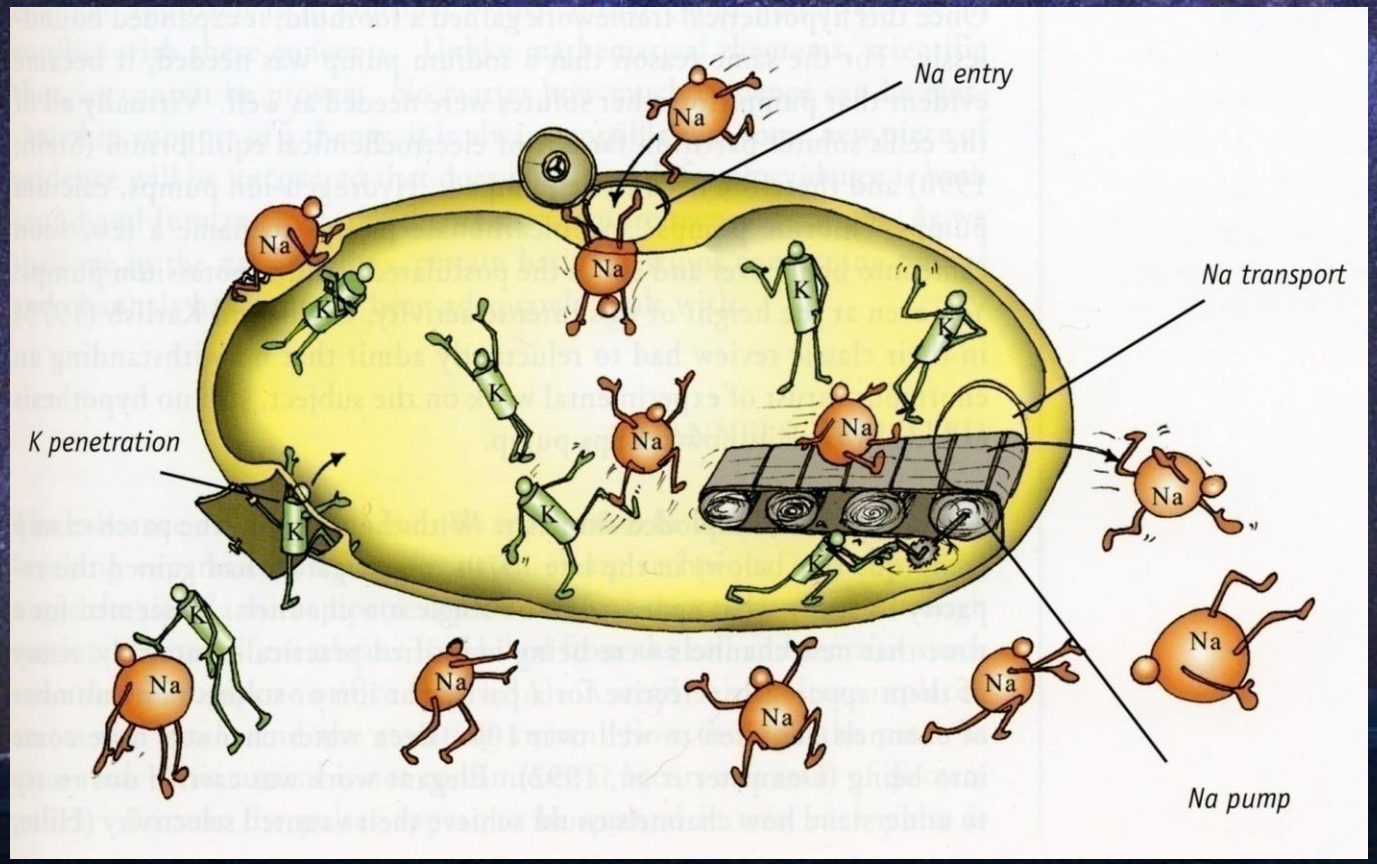


Fundamental physical properties of the living cell

1. Selective permeability (semipermeability).
2. Selective accumulation of solutes (accumulation of K^+ and exclusion of Na^+).
3. Osmotic stability.
4. Generation of electric potentials.

Our understanding of the physical nature of these properties dramatically affect our understanding of cellular function and, accordingly, on the methodology of solving the problem of the origin of life.

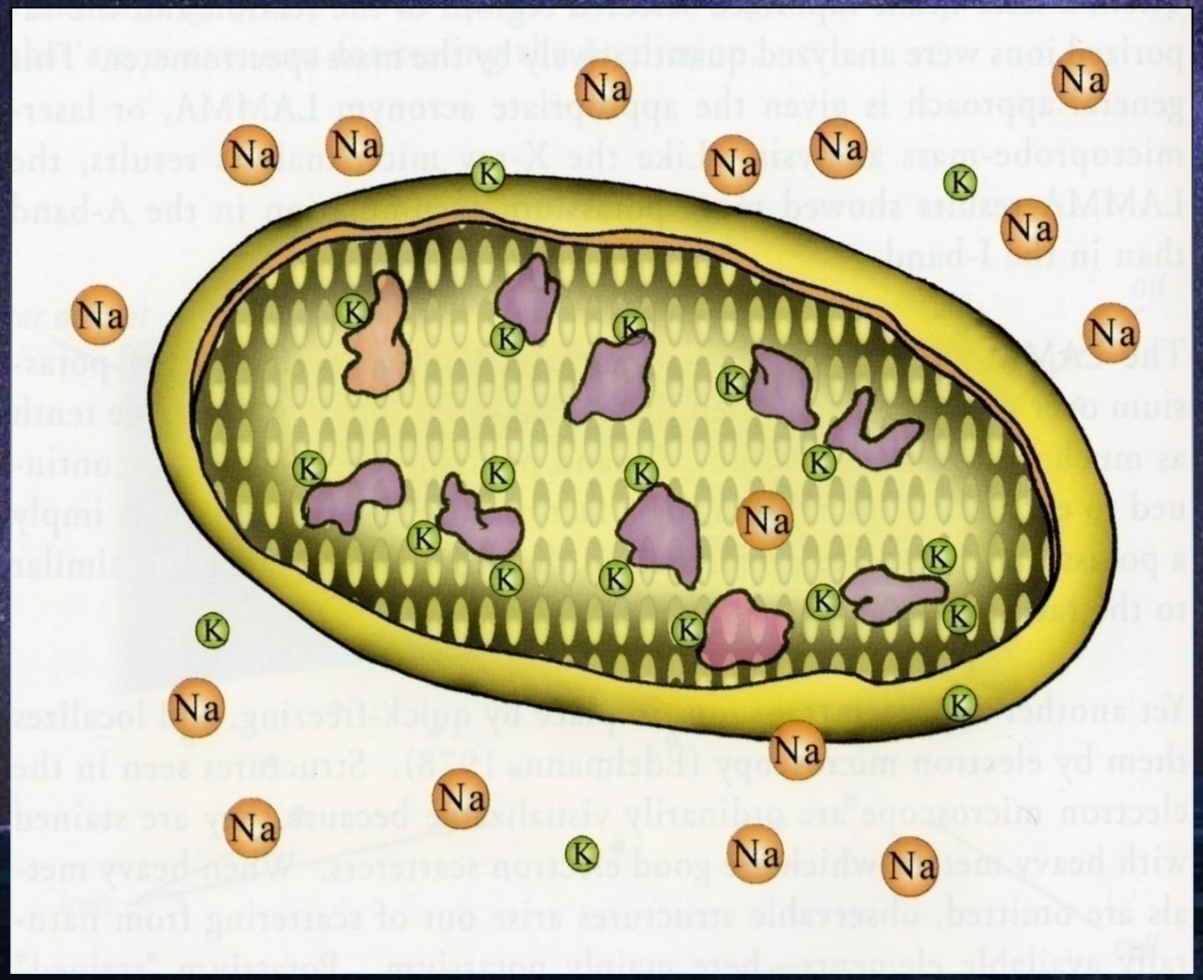
The standard, membrane, model of the living cell



The physical state of water and ions inside the cell and outside is the same.

The origin of life is reduced to the problem of the origin of the "living" membrane and the mechanism of energy supply of sodium pump.

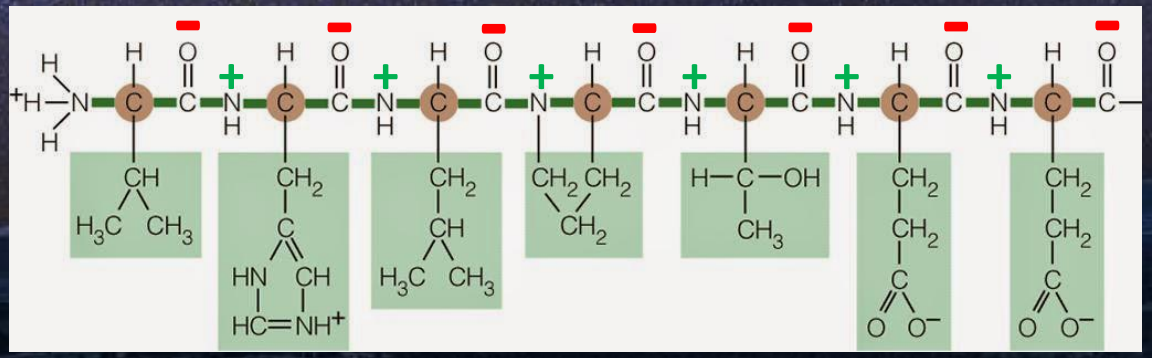
The phase model of the living cell

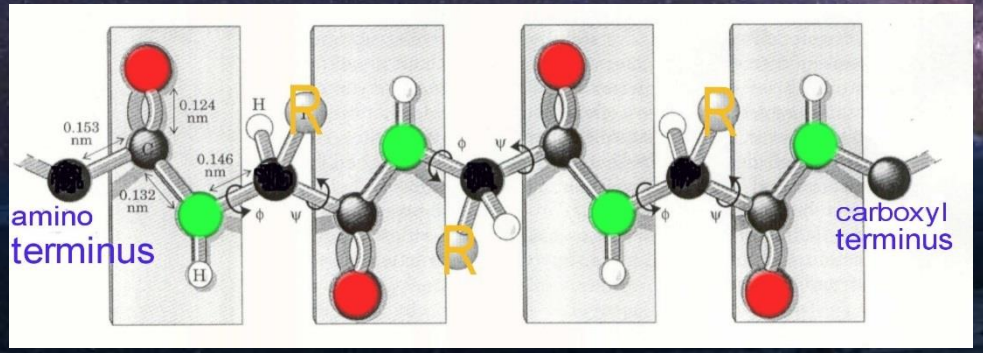


Adsorption by proteins of the main portion of intracellular water and basic cation (K^+) leads to a change in the physical state of particle majority in the system and makes the cell a phase immiscible with surrounding solution.

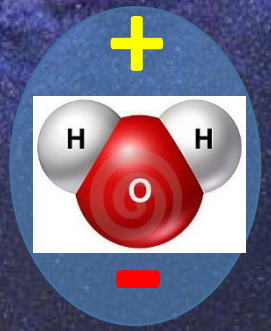
The origin of life is reduced to only *one* key event – to spontaneous formation of polypeptides.

Proteins with extended conformation only are phase-making ones

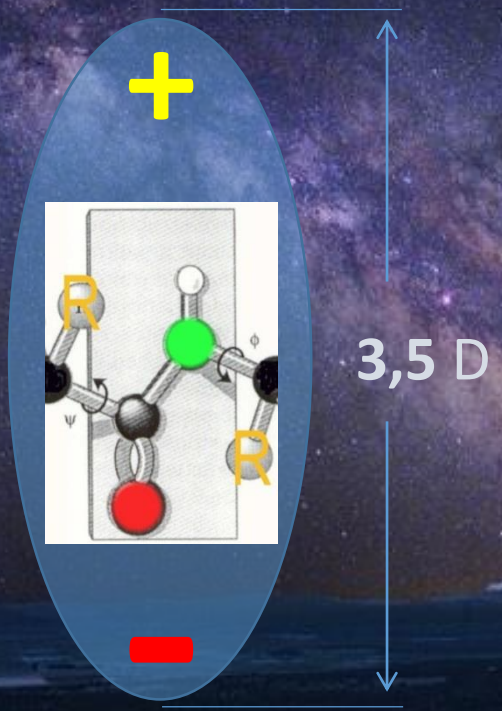




Dipole moments of functional groups of peptide bond are stronger than that of water



1,85 D → 2,9 D (+60%)
(gas → liquid)



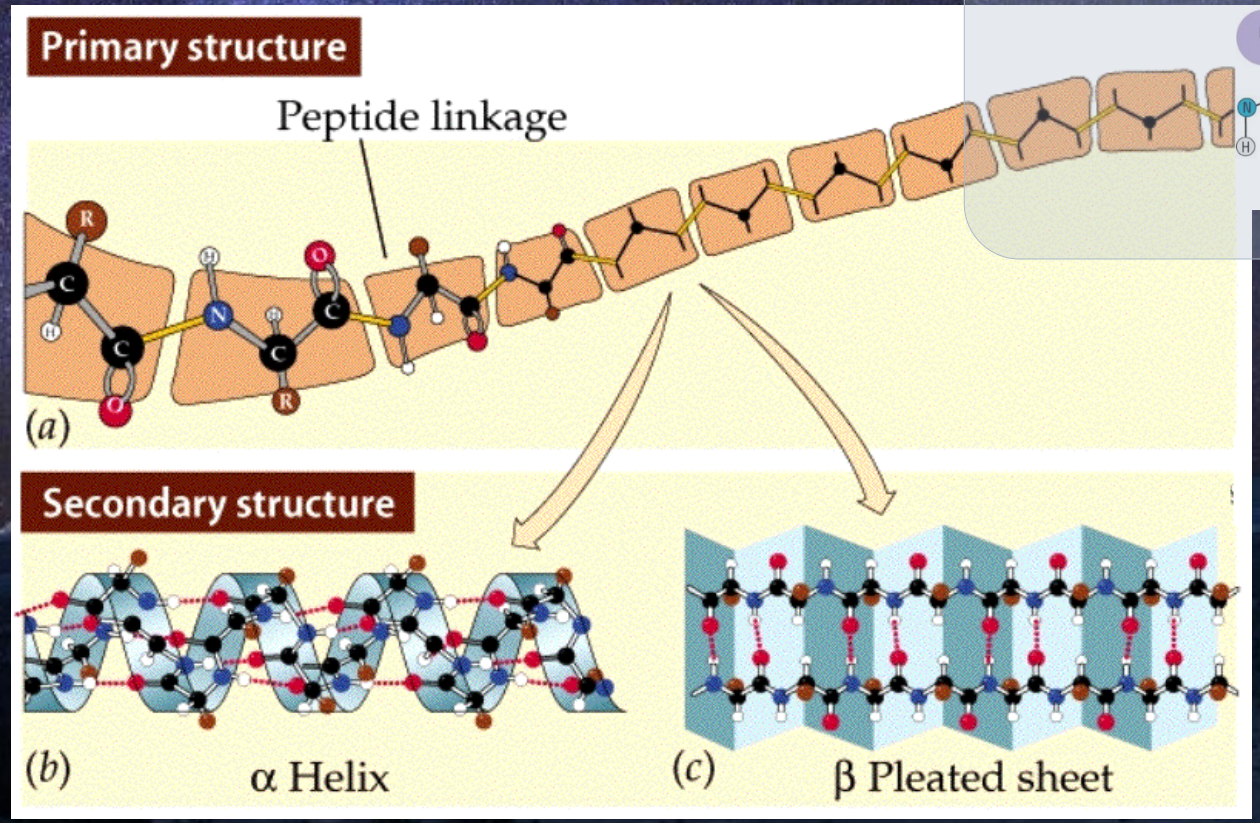
Dipole moment of

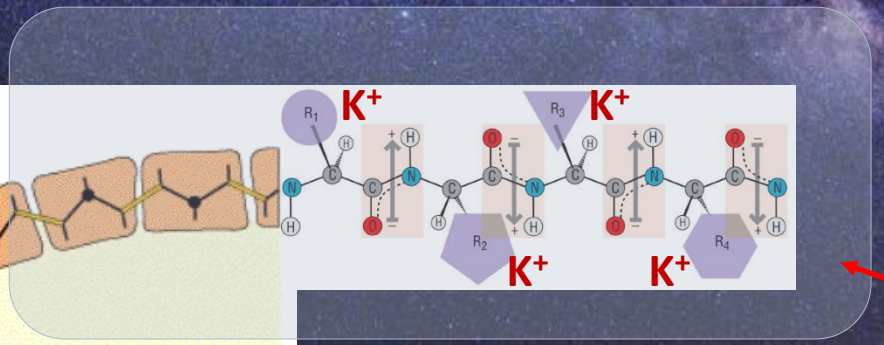
carbonyl group: **2,7** D (1,85 + 46%);
peptide bond: **3,5** D (1,85 + 89%).

Collins J.M. and Leadbeater N.E. Microwave energy: a versatile tool for the biosciences. Org. Biomol. Chem., 2007, 5: 1141-1150.

The dipole moment of water molecules interacting with protein is stronger than their dipole moment in liquid phase

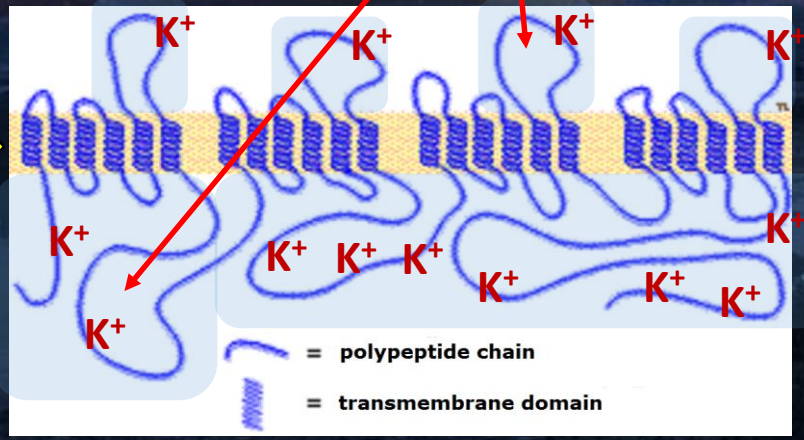
Hydrophilicity / hydrophobicity of a polypeptide is determined by its conformation



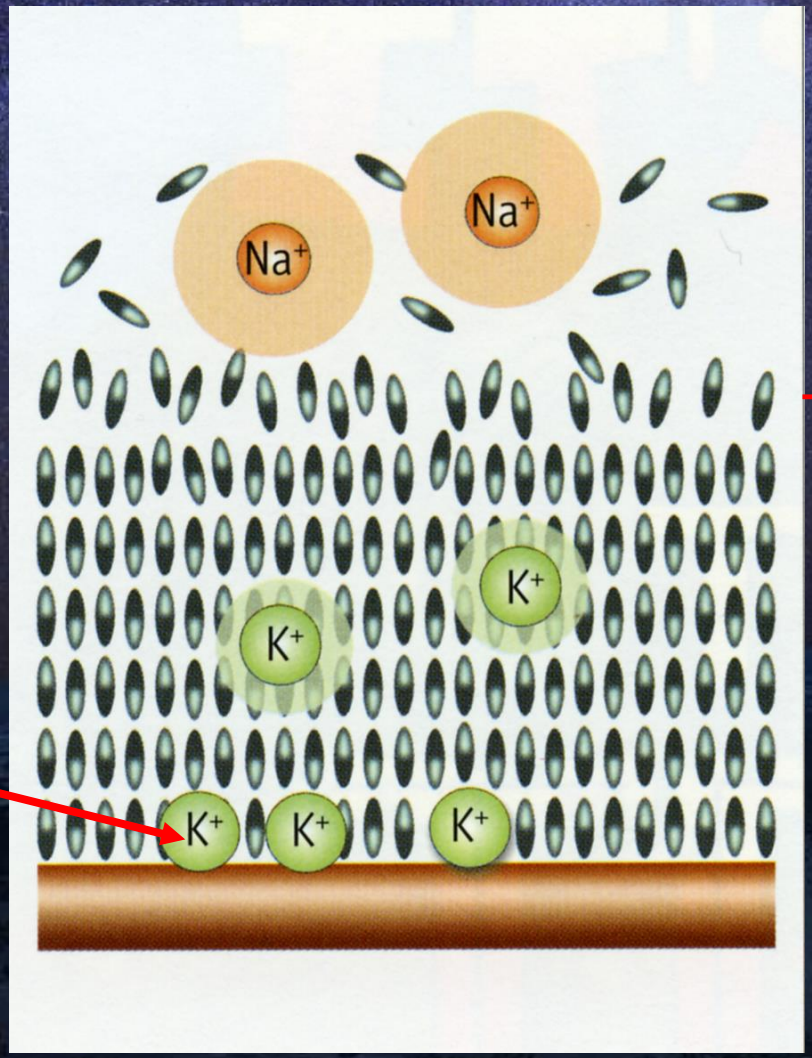


α-Helices in lipid phase

Phases of adsorbed water



The structure of biophasosome, protein-adsorbed water complex



Bulk phase (free) water

Adsorbed/free water interface

Adsorbed water, aqueous phase with reduced solvency

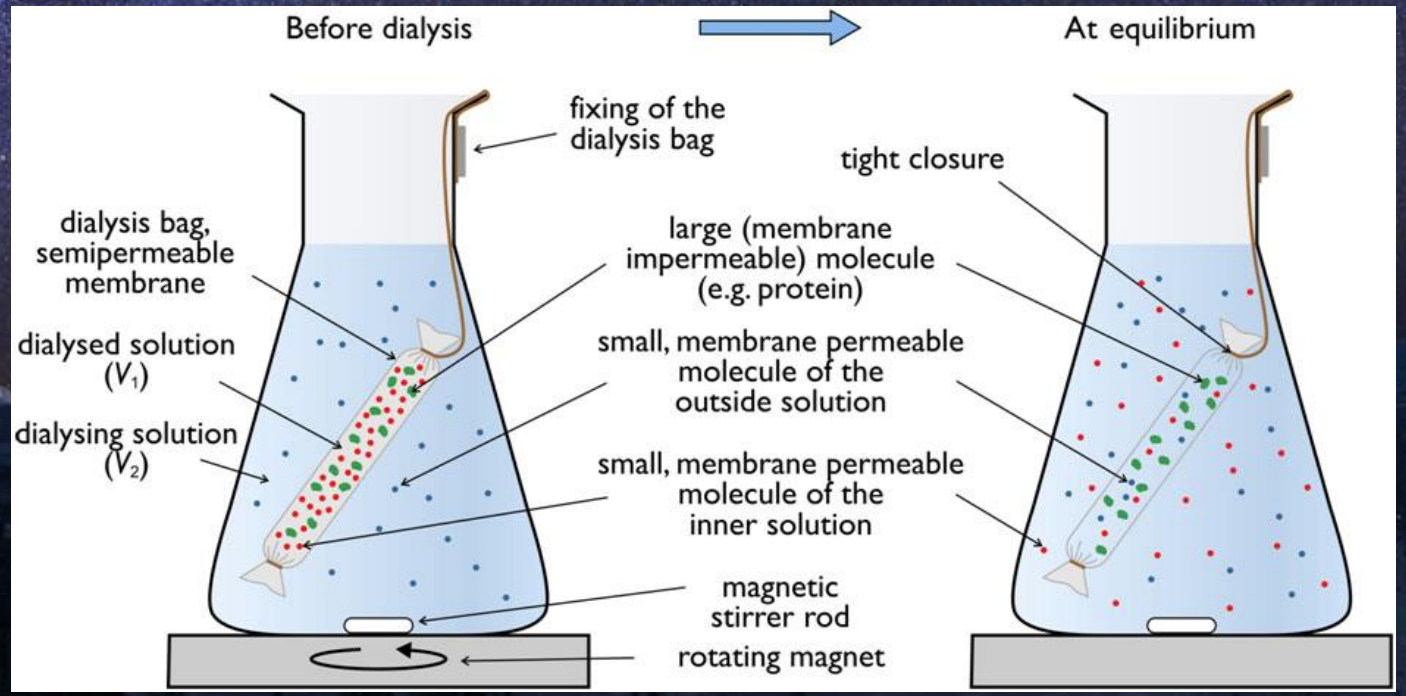
Adsorbed K^+

Polypeptide chain as adsorbent

Dialysis as a method of investigation of solute distribution in condition of diffusion equilibrium

Before dialysis

At diffusion equilibrium



A quantitative measure of equilibrium (steady state) distribution of solutes is the distribution coefficient

$q = C_c/C_s$,

where C_c, concentration of tested solute in water of dialysis bag (or some another system), C_s, concentration of the same solute in the medium.

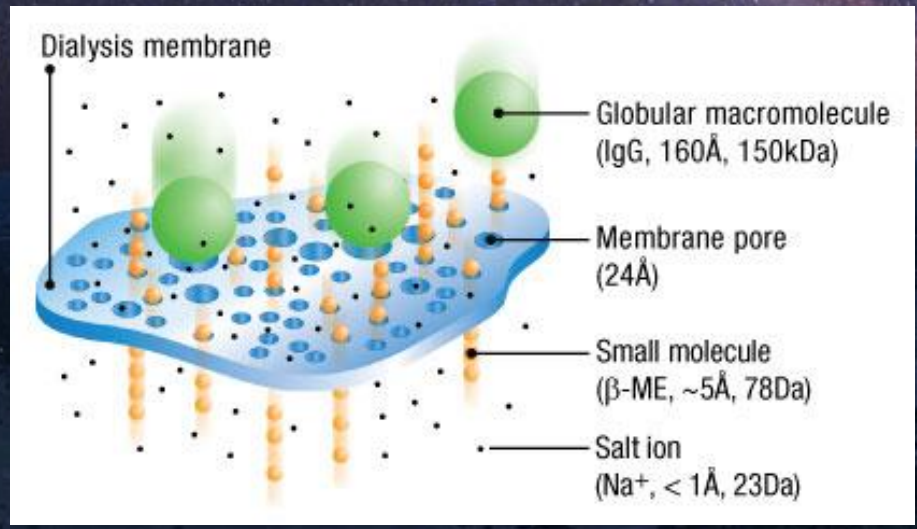


Table I Equilibrium distribution coefficients (q) of solutes between studied systems (solutions of macromolecules, coacervates, living cells), on the one hand, and bathing solution, on the other, depending on their molecular mass. $q = C_c/C_s$, where C_c, concentration of tested solute in water of dialysis bag (or some another system), C_s, concentration of the same solute in the medium.

Solute	MM	q							
		n-Hem	d-Hem	PEO	Gelatin	Coacervates	Muscle T	Muscle P	Dowex 50
Methanol	32.04	-	-	-	0.94	-	-	0.91	0.61
Ethanol	46.07	-	-	-	0.91	-	-	0.81	-
Acetamide	59.07	-	-	-	-	-	-	1	-
Urea	60.06	-	-	-	-	-	-	1.05	-
Isopropanol	60.1	-	-	-	0.91	-	-	-	-
n-Propanol	60.1	-	-	-	0.93	-	-	-	-
Ethylene glycol	62.07	0.998	0.998	0.949	0.87	-	-	1.02	0.67
n-Butanol	74.12	-	-	-	0.91	-	-	-	-
Tert-Butanol	74.12	-	-	-	0.91	-	-	-	-
1,2-Propanediol	76.09	-	-	-	0.89	-	-	0.834	-
DMSO	78.13	-	-	-		-	-	0.72	-
1,2-Butanediol	90.12	-	-	-		-	-	0.87	-
2,3-Butanediol	90.12	-	-	-	0.89	-	-	-	-
Glycerol	92.09	0.958	0.887	0.909	0.9	-	-	1	0.49
3-Chloro-1,2-Propanediol	110.54	-	-	-		-	-	0.893	-
Pinacol	118.17	-	-	-	0.86	-	-	-	-
Erythritol	122.12	1.053	0.856	0.92	-	-	-	0.29	-
D-Arabinose	150.13	-	-	0.861	-	-	-	0.27	-
D-Ribose	150.13	-	-	-	-	-	-	0.26	-
D-Xylose	150.13	0.98	-	0.864	-	-	-	-	-
L-Arabinose	150.13	-	-	-	-	-	0.46	0.27	-
L-Xylose	150.13	-	-	-	-	-	-	0.26	-
Xylitol	152.15	0.936	0.837	-	-	-	-	0.22	-
D-Fructose	180.16	-	-	-	0.95	-	-	-	-
D-Glucose	180.16	-	-	0.879	0.94	-	-	0.227	0.22
L-Galactose	180.16	-	-	-	-	0.61	0.36	-	-
D-Mannitol	182.17	0.961	-	0.82	-	-	-	0.217	-
D-Sorbitol	182.17	1.035	0.84	-	-	-	-	0.227	-
D-Trehalose	342.3	0.997	0.713	0.87	-	-	-	-	-
Lactose	342.3	-	-	-	-	-	-	-	-
Sucrose	342.3	0.976	0.627	0.768	0.77	0.60	0.28	0.132	0.24
D-Raffinose	594.51	0.971	0.552	-	0.62	-	-	0.1	-

Equilibrium distribution coefficients (q) of solutes between studied systems (solutions of macromolecules, coacervates, living cells), on the one hand, and bathing solution, on the other, depending on their molecular mass

Columns n-Hem…Gelatin (Ling & Hu 1988; Ling 1993),
Coacervates (Troshin 1966, Tab.104);
Muscle T (Troshin 1966, Tab.22), Rana temporaria;
Muscle P (Ling et al. 1993), Rana pipience, DMSO, dimethyl sulfoxide;
Dowex 50 (Ling 1965), cation (sulfonate) exchange resin, spherical material of 20-50 mesh.

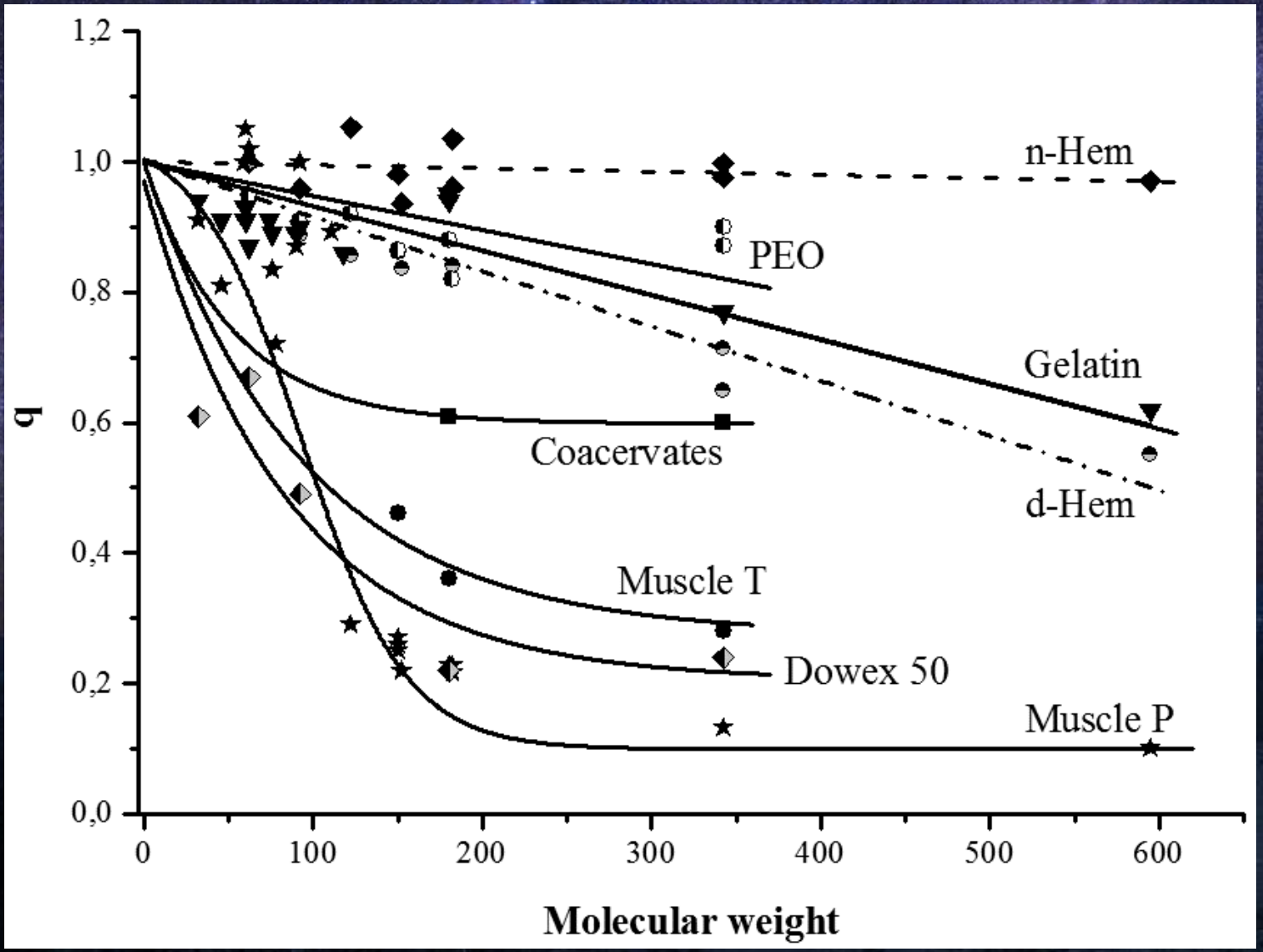
Ling, G. N. (1965). The physical state of water in living cell and model systems. Annals of the New York Academy of Sciences, 125(2), 401-417.

Ling, G. N. (1993). A quantitative theory of solute distribution in cell water according to molecular size. Physiological chemistry and physics and medical NMR, 25, 145-145.

Ling, G. N., and Hu, W. (1988). Studies on the physical state of water in living cells and model systems. X. The dependence of the equilibrium distribution coefficient of a solute in polarized water on the molecular weights of the solute: experimental confirmation of the" size rule" in model studies. Physiological chemistry and physics and medical NMR, 20(4), 293-307.

Troshin, A.S. (1966). Problems of Cell Permeability. Pergamon Press, Oxford.

The dependence of distribution coefficient (q) of solutes between tested system and bathing solution depending on their molecular mass (see Table 1)



n-Hem, native bovine hemoglobin solution (39%);
d-Hem, NaOH-denatured bovine hemoglobin (20%), dialysis was carried out in an alkaline solution containing 0.4 M NaOH;
PEO, poly (ethylene oxide) (15%);
Gelatin (18%);
Coacervates, gelatin-gum arabic complex at 40 °C;
Muscle T, frog calf muscle (Rana temporaria) at 18-20 °C;
Muscle P, frog sartorius muscle (Rana pipiens) at 0 °C;
Dowex 50, the cation (sulfonate) exchange resin, spherical material of 20 to 50 mesh.

The non-uniform distribution of solutes (when q < 1) indicates the phase differences between bulk water and (i) aqueous polymer solutions, (ii) models and (iii) living cells.

Experimental evidences for existence of adsorbed water phase at hydrophilic surfaces

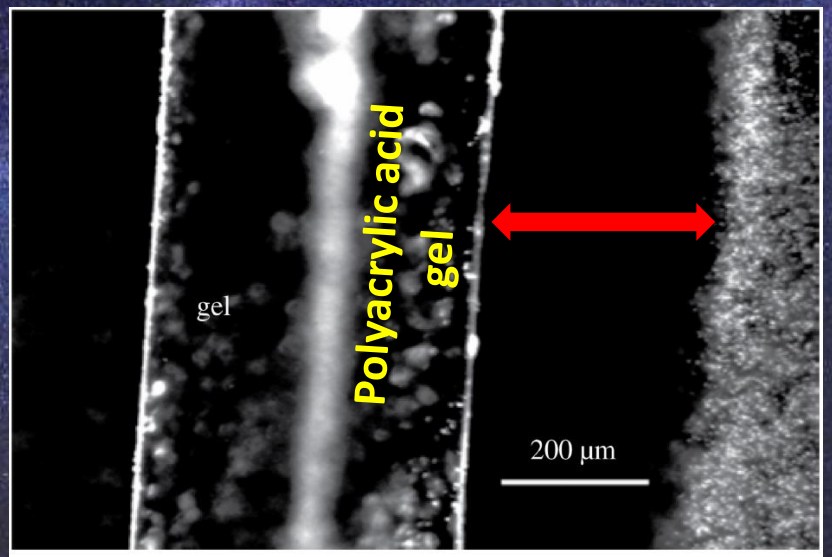
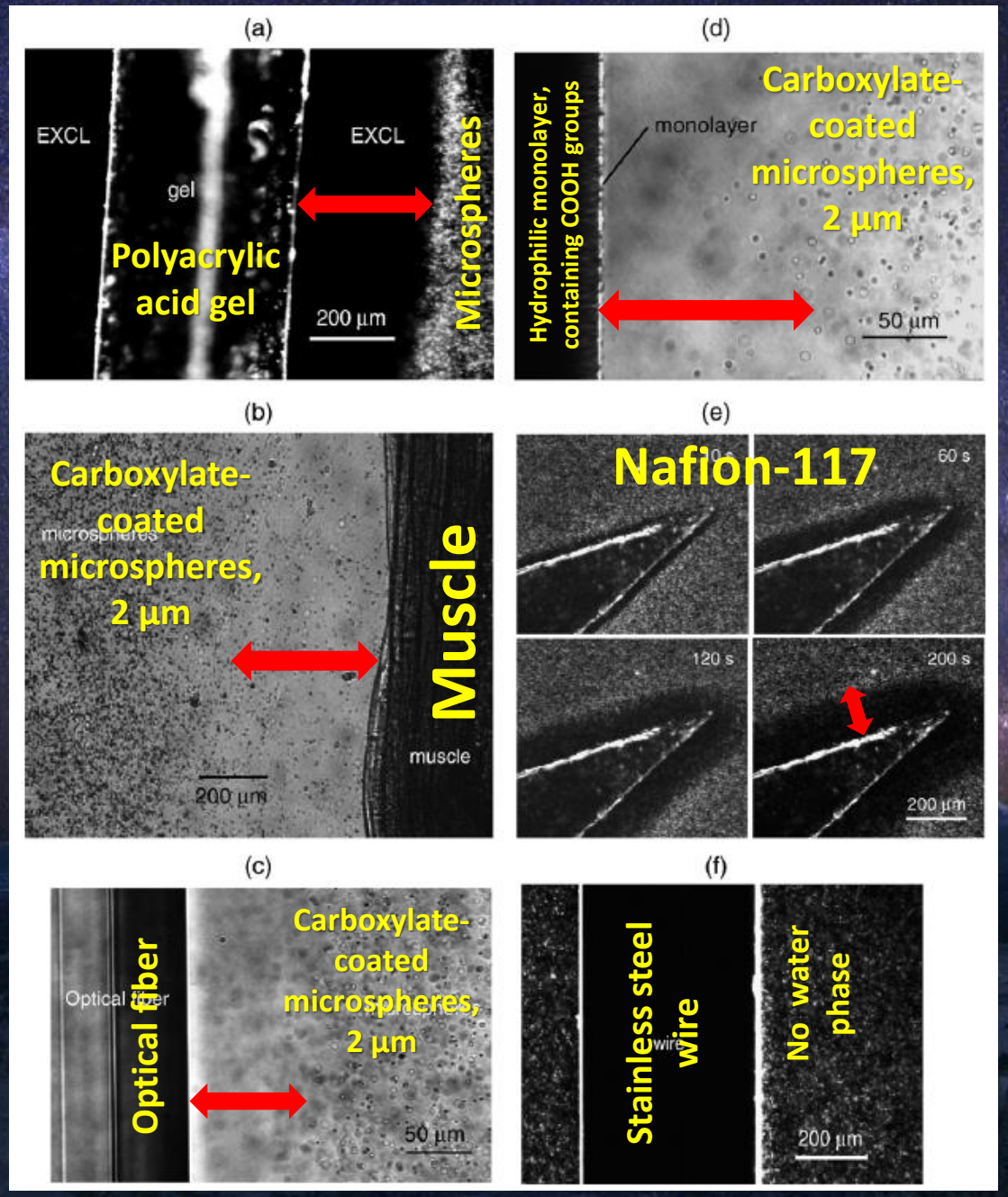


Figure 1.
Solute exclusion in the vicinity of polyacrylic-acid gel. The gel was placed on a coverslip, superfused with a suspension of 1-µm carboxylate-coated microspheres and observed in an inverted microscope. Image was obtained 20 min after superfusion. (Fuzzy vertical line within gel is optical artifact.) Microspheres move away from gel, leaving regions (black) on either side of gel that are devoid of them. Microspheres seen on right edge of figure.

Pollack G.H. Water, energy and life: fresh views from the water's edge. Int J Des Nat Ecodyn. 2010, 5(1): 27–29.

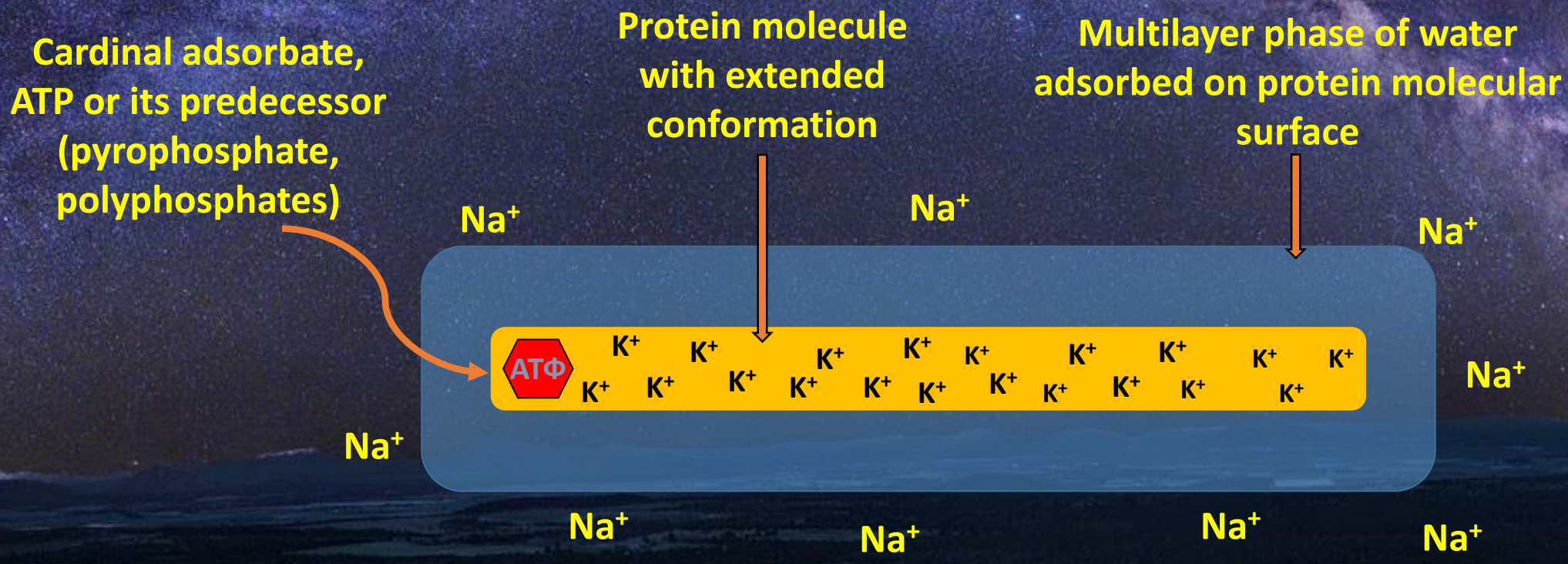
Zheng JM, Chin WC, Khijniak E, Khijniak E Jr, Pollack GH. Surfaces and interfacial water: evidence that hydrophilic surfaces have long-range impact. Adv Colloid Interface Sci. 2006 Nov 23;127(1):19-27.

<--Red arrows indicate thickness of adsorbed water phase with a reduced solvency



Biophasosome or Nanocell,

minimal cell/protocell providing the physical conditions required for origin of life and evolution



Separation of internal environment from external one occurs without lipid membrane, ion channels and pumps; energy generation mechanism is not needed

The standard (membrane) model of the living cell is not able to explain the electrical activity of Fox's proteinoid microspheres

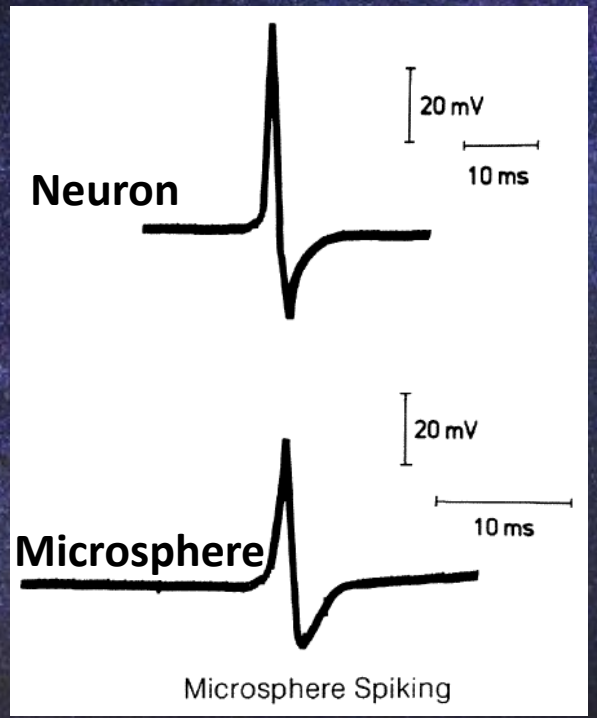


Fig. 6. Action potential resembling that of neuron. (Upper) Spiking in crayfish stretch receptor neuron. (Lower) Spiking in microsphere of 2:2:1-proteinoid. (By Dr. A. Przybylski.)

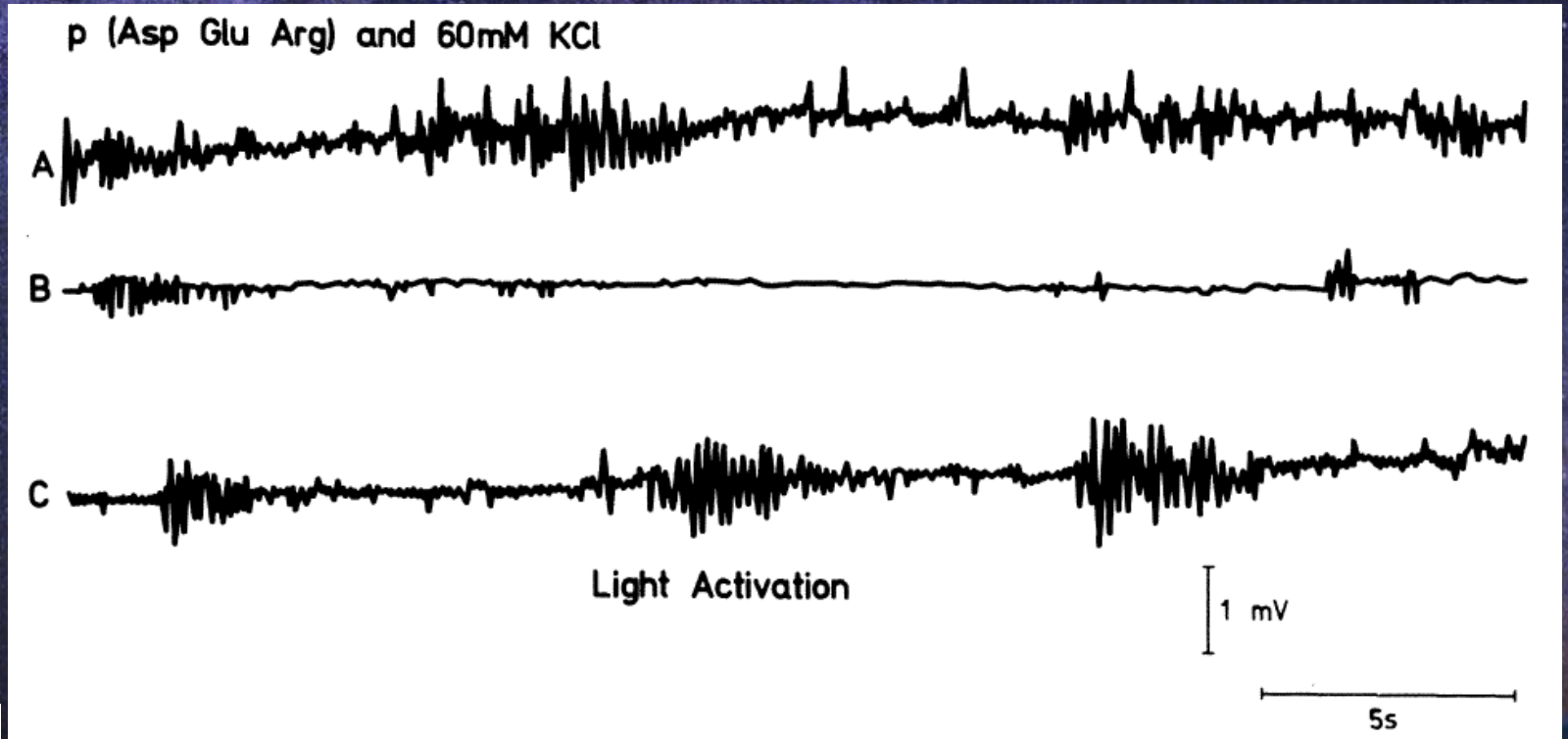
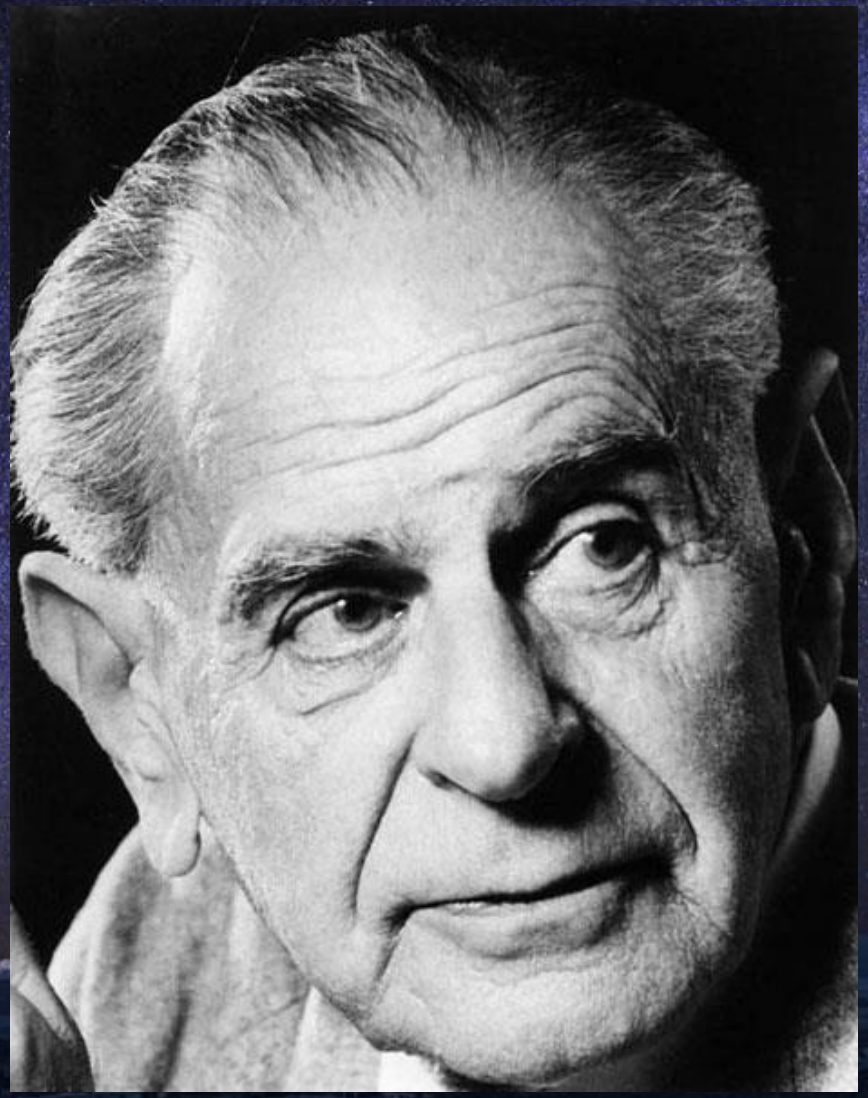


Fig. 7 A–C. Electrical activity begins with illumination (10 lux) at **A**. It dies off when light is extinguished (**B**), and it begins again with reillumination (100 lux) at **C**

Fox, S. W. (1992). Thermal proteins in the first life and in the "mind-body" problem.
In: Evolution of Information Processing Systems (pp. 203-228). Springer Berlin Heidelberg.

Microspheres have no lipid membranes or sodium pumps, or specific ion channels, but nevertheless they generate action potentials

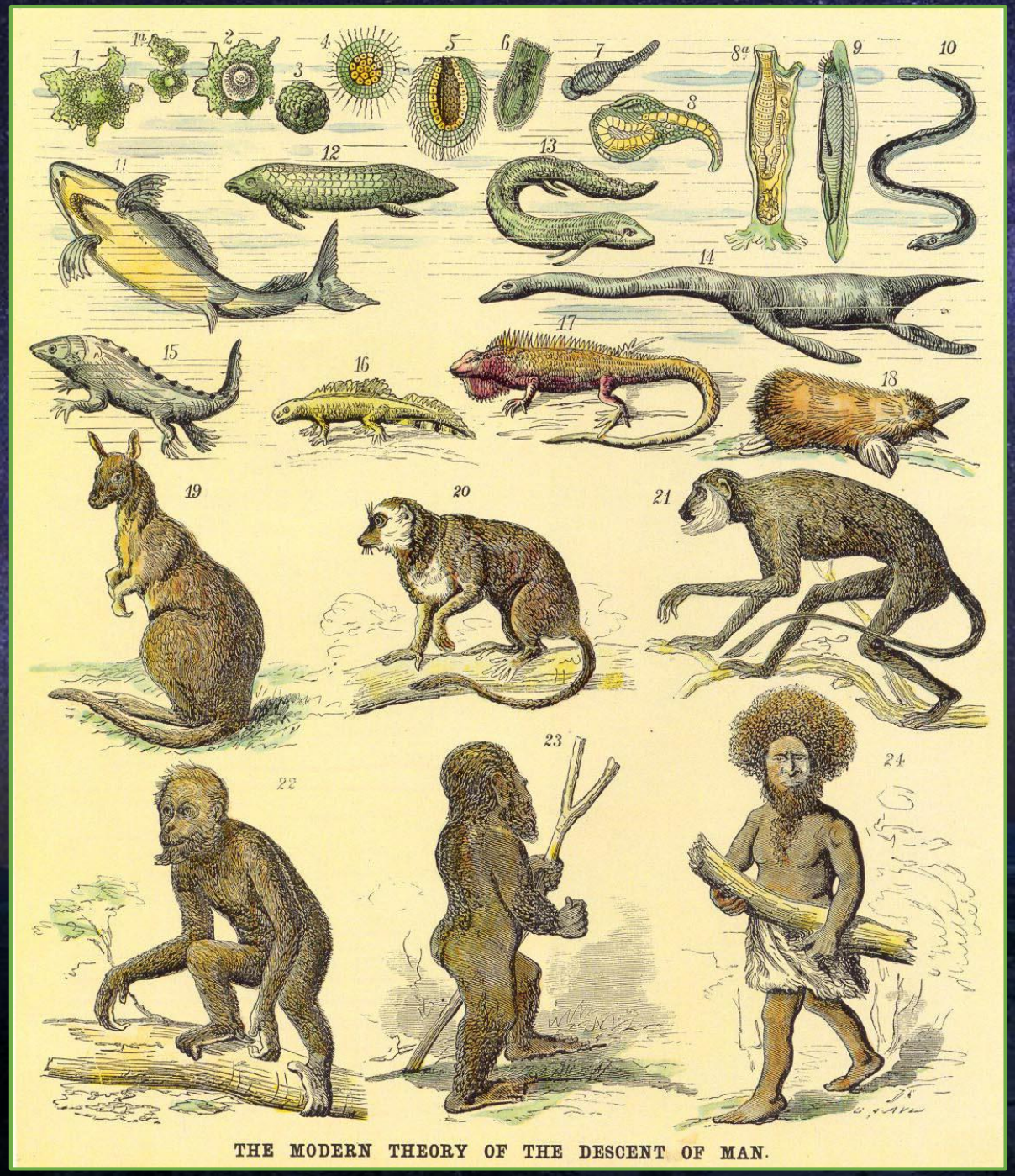


Karl Raimund Popper

"The criterion of the scientific status of a theory is its falsifiability, or refutability, or testability."

Popper K.R. Conjectures and refutations. The Growth of Scientific Knowledge. Basic Books, New York (1962), p. 37.

To falsify the phase bulk approach is necessary to give another explanation for the non-uniform distribution of solutes between the considered phase systems and the environment without involvement of the properties of water.



Since the origin of the first protocell and up today the physical mechanism of the equilibrium distribution of solutes between the cell and its environment has remained unchanged

Membrane or phase? What do experiments argue?

Membrane approach

Proved

1. Spontaneous synthesis of lipids.
2. Spontaneous synthesis of amino acids.
3. Spontaneous synthesis of polypeptides.
4. Self-assembly of lipids to form membrane.

Not proved

5. Spontaneous formation of Na,K-pumps.
6. Spontaneous formation of specific ion channels.
7. Spontaneous formation of functional lipid membrane with built-in ion channels and Na,K-pumps.
8. Spontaneous formation of energy supply mechanism needed for molecular pumps.

VS

Phase bulk approach

Proved

1. Spontaneous formation of amino acids.
2. Spontaneous formation of polypeptides.
3. Spontaneous association of polypeptides to form a protocell.
4. Multilayer adsorption of water by polypeptides.
5. Protocell ability to accumulate K^+ (Fox's microspheres).
6. Maintaining an integrity of protocell (biophasosome) does not require permanent supply of energy.
7. Spontaneous formation of ATP precursors, pyrophosphate, polyphosphates.

Main conclusions:

- the sorption properties of phase-making proteins are able to explain earliest, elementary steps of the origin of life creating physical conditions needed for life processes and, therefore, for evolution;

- the fundamental physical properties of the living cell remains qualitatively unchanged throughout all stages of evolution — from the origin of life to the present;

- the minimal cell is a minimal single-protein-based structure, which has inseparable four fundamental physical properties of the living cell.

Matveev, V.V. (2017) Comparison of fundamental physical properties of the model cells (protocells) and the living cells reveals the need in protophysiology, International Journal of Astrobiology, 16(1): 97–104

The Biophase
is the Physical Basis of Life

Astrobiology


The first version of this video was published on July 24, 2016.
This version has only technical improvements.
An internet robot has read the text.