Cytomembranes

The *membrane of the cytoplasm* has metabolic functions and protective mechanisms, the solution of which, depending on the biomedium, requires special structures. Membranes, typically, are areas of contact, which separate and mediate. In biology, barriers and mediating surfaces form between morphological and functional units. Membranes fit together without steps and thus include an ecological space. They account for the ingestion, penetration and elimination of substances in this space. The substances can be ingested solid (= phagocytosis) or liquid (= pinocytosis); the penetration is called permeation, and the substances are eliminated in a liquid (= secretion) or solid (= extrusion) form.

The *main function* of the cytomembranes, namely the contact to the environment for the supply of food and protection against harmful influences from outside has antagonistic properties. An increase of the protective function means loss of elasticity, hinders the transport of substances and impairs mobility. Plants reinforce their membranes with cellulose, often by thick layers (bark), animals with scales and spines, or with lime, like the animals in the sea.

The cytomembranes are the *prototype* of the biological membranes inside the organism of the mammals. Their classical description is the *Danielli-Davson model* (Danielli and DAVSON, 1935; DANIELLI, 1967). According to it, the membrane of cytoplasm consists of a continuous layer of probably bimolecular lipoids with an insoluble film of proteins on either side (fig. 9). The protein is said to be bound to the layer of lipoids by electrostatic interaction. Moreover, hexagonal phases are supposed to occur inside the watery mixture of phosphorus-lipoids; they can appear especially at higher temperatures (37°C) and a low content of water (3%) (STOOKENIUS, 1962). For their arrangement, either linear formation of lipoids (fig. 9) or globular patterns are supposed (LEHNINGER, 1968). HASSELBACH showed recently that both formations are found side by side on the same object. Linear lipoids formations and globular arrangements may, consequently, represent different functional conditions on the same membrane.

The Danielli-Davson model is compatible with the unit-membrane concept (ROBERTSON, 1961, 1966; SJÖSTRAND, 1963; YAMAMOTO, 1963) because the latter includes also three layers. The outer contact layer of the protoplasm represents in the electron microscope a structure unit of three layers having a mean thickness of 70 Å. The detail-dates of structure and function were summarisized by SINGER and NICOLSON (1972) in the «fluid mosaic model». The majority of the proteins are understood as integrated «swimming» elements in a «quasi-fluid» Phospholipid-layer.

Biochemistry

Cytomembranes constitute a formation of lipoid and protein molecules. The inner layer of a cytomembrane consists of a bimolecular lipoid formation, whose hydrophobic poles are turned towards each other. The hydrophilous poles however are pointed at the extracellular and intracellular spaces. The lipoids layer is surrounded by a protein layer «outside» and «inside». The pro-

tein molecules constitute unfolded, parallel threads, whose basic direction in the cellular membrane is radial. The protein threads are connected with each other by hydrogen bridges. This pleated-sheet structure explains the elasticity and plasticity of the membrane. Macromolecules can be deposited on the outer and inner sides of the protein layer; this accounts for the high adhesive and binding capability of the membranes.

The differentiated multilayered structure of the cytomembrane provides a several times secured barrier, which is a prerequisite for the bionomy of the enclosed spaces. The organization inside the cell is more differentiated and more complex than the extracellular space. The autonomy of cellular activity and the selective functions of the cell organelles can subsist only while the intracellular complexity continues reciprocally and protected by effective barriers against the extracellular space.

On the other hand, one and the same membrane must regulate selectively the metabolism between the extracellular and intracellular spaces so that substances drawn from the humoral pool for the intracellular metabolic processes can be ingested and superfluous or even harmful substances as well as products of cellular synthesis can be eliminated into the extracellular space. The question whether the cytomembrane has po res is still controversial, but solid and li quid substances can certainly pass, and a gap in the cytomembrane can be made vi sible by lipoid staining. A temporary ga ping in the lipoid layer seems to be the decisive process in the *ingestion* and *extrusion* of larger particles (fig. 29, 176–179).

The lipoid layer is likely to regulate also the *permeation* of dissolved substances through the cytomembrane as well as the *diffusion*. Gaseous substances such as H_2, O_2 and CO_2 permeate readily, electrolytes less so. Neutral lipoids are unsoluable, therefore not permeable, lipoids with acid groups allow to pass the cations, lipoids with alkaline groups the anions (KLIMA, BEUTNER).

Thanks to the different distribution of the ions between the intracellular and extracellular spaces, the cytomembrane

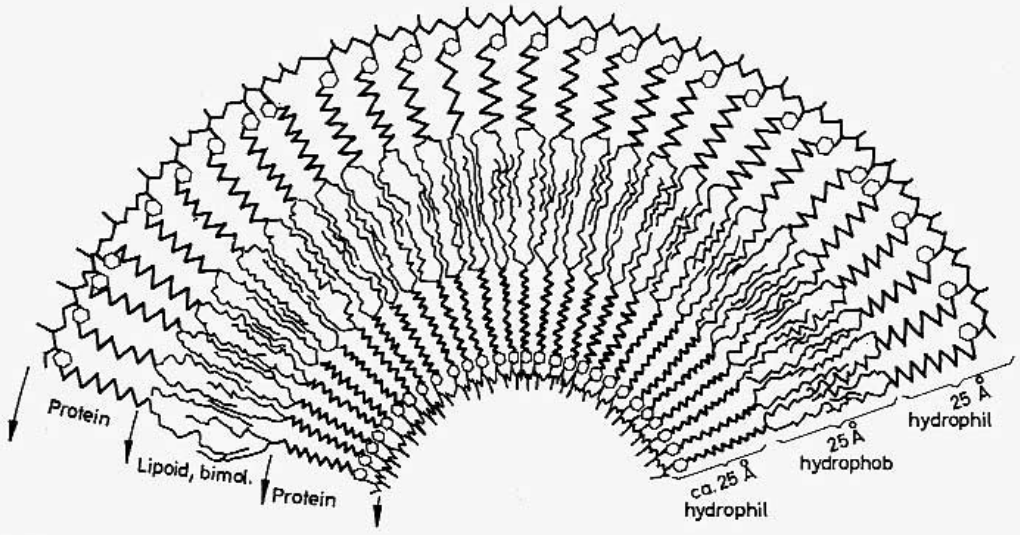

Fig. 9:
Three layers and architectonics of the cytomembrane, which consists, with an average thickness of about 70 Å, of two protein layers and a bimolecular lipoid layer.

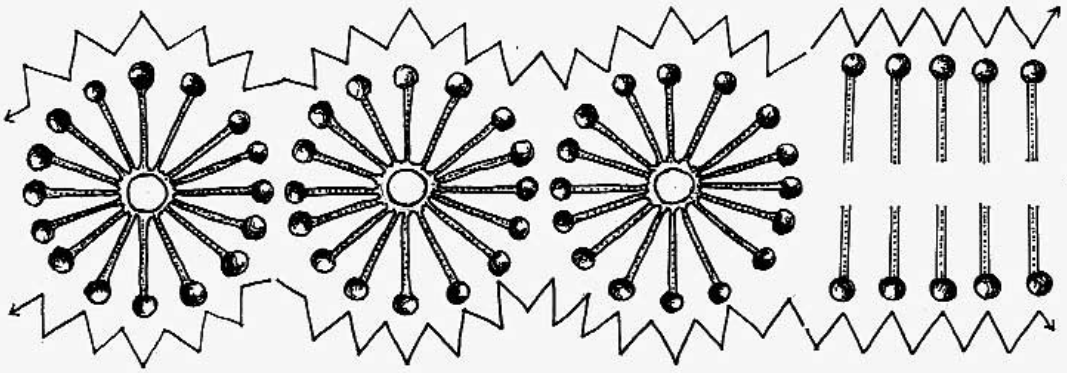

Fig. 10:
Globular arrangement of the membrane layers in a formation favouring the transportation of the membrane.

has an electric potential (= *membrane potential*), which is usually between 50–100 mV, but depends on the functions. This potential compensates the difference of concentrations for K^+- and Cl-ions. In nerve cells, the resting potential is 50 mV, the action potential (stimulation) is 80–130 mV. The inner side of the membrane is negative when at rest, and positive when excited.

Elementary or alpha-cytomembranes not only serve for cellular boundary barriers but also within the cell divide regions with different functions to form *bionomous units*. A tubular system, the *endoplasmatic reticulum or ergastoplasm*, forms spaces arranged like conveyor belts for cellular synthetic functions (hormones, ferments, antibodies). Cytomembranes enclose *vacuoles*, intracellular cavities containing fluids and substrates, which are better referred to as *vesicles* (small) or *cisterns* (large) because they are not «empty». Finally the nucleus, subject to its own laws, is separated from the cytoplasma space by the nuc-

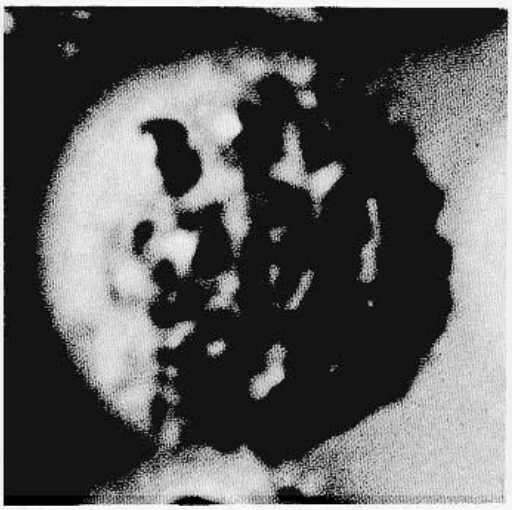

Fig. 11:
Membrane activity of (peritoneal) exudate cells with visible convex and concave areas on the surface.

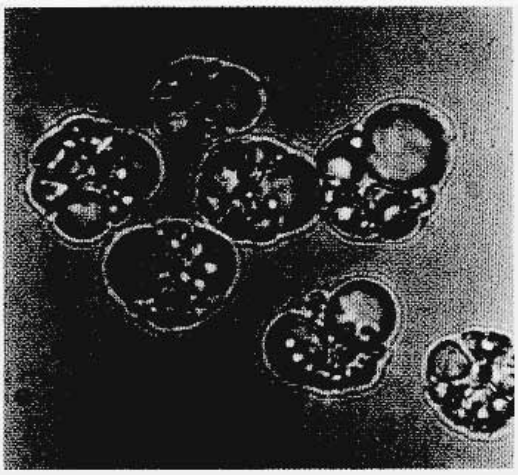

Fig. 12:
Membrane activity of living (peritoneal) exudate cells as seen in the phase-contrast microscope. Several ecological spaces surrounded by membranes within the cells are visible.

lear membrane (fig. 4, 5), same as the energy stations of the cell, the mitochondria (fig. 36–41).

Membranes create and separate more functional spaces where metabolic processes can take place, and whose substrates might endanger or even destroy other parts of cells and cellular organelles unless they were delimited by membranes. Pinocytosis causes in this way vesicles filled with fluid of the extracellular space i.e. having fluids of other quality and concentrations of electrolytes, to be transported through the space of cytoplasm to the Golgifield. Phagocytosis causes solid substances to disintegrate in «digestive vacuoles» (see fig. 176) enclosed by membranes with a pH hardly compatible with the life of the cytoplasmatic space. Here, separated and yet connected with the cytoplasm by permeation and diffusion, the ingested material is broken down into the steps of degradation the cytoplasm can take up without a risk.

Membrane systems separate and connect units of biological functions unbalanced biochemically and physically. The chemico-physical unequality necessary for the performance of differentiated functions can be maintained only by membranes. Membrane systems, consequently, are boundary surfaces regulating selectively the ingestion and extrusion of substances and the exchange of information between the function

Fig. 13:
Bulges in the cytoplasm-membrane (arrow) of a monocyte. Nuclear membrane (wedge) comparatively thick (1:26,000).

spaces. The development from the monocellular being to the highly differentiated organisms of mammals is inconceivable without systems of membranes.

The aging process of living beings is probably accounted for, above all, by an impairment of the functions of cytomembranes.

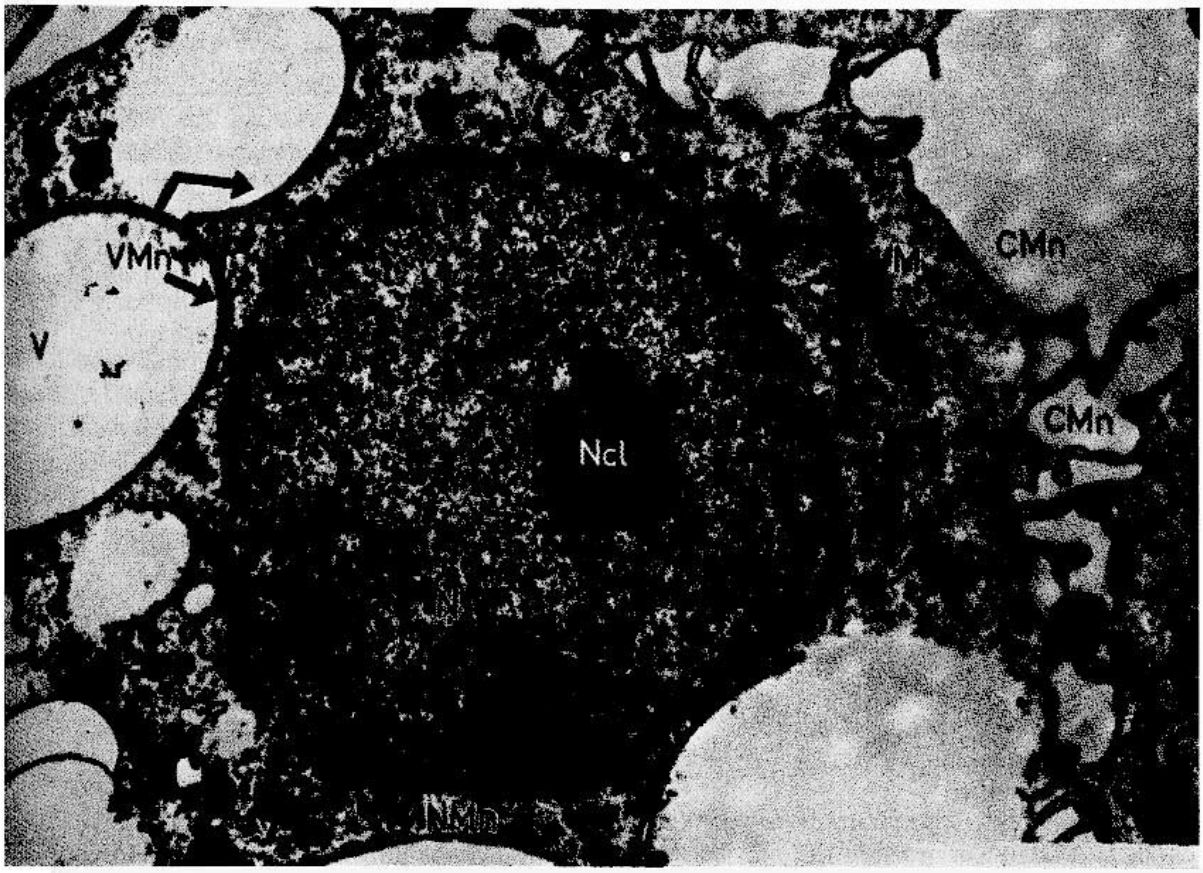

Fig. 14:
Most of the cellular organelles are *ecological spaces* surrounded by membranes such as nucleus, mitochondria, Golgi-apparatus, endoplasmatic reticulum and cytoplasm.

Membrane systems of a monocytary cell.
C Mn = cytoplasm membrane
N Mn = nuclear membrane
V Mn = vacuoles membrane
M = mitochondria, the membrane of which can also be seen
N = nucleus
Ncl = nucleolus
V = vacuole
Electronoptically 1 : 15,000
(SCHMID, WACHSMUTH and WALDECK).

Tab. 1: **Enzymes of the cytoplasm membrane**

Enzyme (synonym) activating ion	Enzyme commiss. No.	Tissue cell-type	Species
acetylecholinesterase	3.1.1.7.	brain synapsis	rat
		erythrocytes	man
alkaline phosphatase	3.1.3.1.	liver	rat
		intestine	rat
		thymocytes	calf
K^+		liver	rat
		kidney	
acid phosphatase	3.1.3.2.	cells	man
		liver	rat
		lymphocytes	pig
		thymocytes-t	calf
phosphatidase-phosphatase	3.1.3.4.	liver	rat
5-nucleotidase	3.1.3.5.	brain: neurons	rabbit
		synaptosomes	rat
		KB-cells	man
		liver	rat
		lymph-nodes, mesent.	pig
		thymocytes	calf
		hela-cells	man
		fat-cells	rat
phosphodiesterase I	3.1.4.1.	liver	rat
		kidney	rat
		hela-cells	man
aminopeptidase (cytosol)	3.4.11.1.	liver	rat
intestine			rat
adenosintriphosphatase	3.6.1.3.		
ATPase Ca^{2+} and Mg^{2+}		liver	mouse
MG^{2+}		liver	mouse
		erythrocytes	man
		thymocytes	calf
		thyroid gland	cat
adenosintriphosphatase	3.6.1.3.		
MG^{2+}, K^+ and Na^+		brain: neuron	rat
		synaptosomes	man
		KB-cells	mouse
		liver	rat
			rat
		heart	man
		erythrocytes	man
		hela-cells	cat
		thyroid gland	rat
		cross-striated muscle	rat
		fat-cells	

Enzyme (synonym) activating ion	Enzyme commiss. No.	Tissue cell-type	Species
nucleotide-pyrophosphatase	3.6.1.9.	liver	guinea-pig
			rat
adenyl-cyclase	4.6.1.1.	liver	rat
F^-		kidney	rat
		thyroid gland	cat
entoenzymes on the outside of the plasma-membrane of intact cells			
alkaline phosphatase (p-nitrophenyl phosphatase	3.1.3.1.	polynucl. leukocytes	guinea-pig
5′ nucleotidase (AMPase)	3.1.3.5.	polynucl. leukocytes	guinea-pig
aminopeptidase (cytosol)	3.4.11.1.	hepatocytes	man
adenosintriphosphatase (ATPase)	3.6.1.3.	polynucl. leukocytes	guinea-pig
nucleotide-pyrophosphatase	3.6.1.9.	hepatocytes	man