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PERMEABILITY THROUGH AN ANIMAL MEMBRANE

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ABSTRACT

Transport of various non-electrolytes, namely, water, acetamide, urea, glucose and sucrose has been studied through a urinary bladder of goat. it has been found that the flow through the membrane is neither diffusive nor viscous but flow through certain number of capillaries of membrane is diffusive and viscous through the rest.

INTRODUCTION

TRANSPORT across natural membranes is a complex phenomenon[1,2]. Since the pore size in such membranes is comparable to the molecular size and channels have undefined geometry and complex surface characteristics, experimental studies are difficult. Earlier studies on transport processes, in both artificial[3] membranes (analogous to the natural membranes[4,5]) and in natural membranes[6], have revealed some useful information. From these studies on permeability of membranes, it can be assessed[7]—(*i*) whether the movement occurs through the bulk of the membrane or through specific limited region of membrane, (*ii*) whether it is brought about by the action of the specific membrane components which are of use in explaining structural relationship of the membrane with permeating species.

With these objectives, an experiment on membrane transport is described in the present communication, using the urinary bladder of a goat in presence of water, urea, acetamide, glucose and sucrose.

EXPERIMENTAL

The urinary bladder of goat was equilibrated with urea solution and fixed in rubber gaskets[8]. The flow volume was measured by noting the rate of advancement of liquid meniscus in a capillary of radius 0·024 cm. The solutions were preheated to the temperature (25° ± 0·01° C) of the experimental cell. The diffusion coefficients were calculated from the viscosity data of solutions as suggested earlier[9].

RESULTS AND DISCUSSION

Transport equation for the flow of matter in presence of pressure difference alone through a membrane reduces to[10]

$$J_v = L\Delta P \quad (1)$$

where J_v is the volume flow of matter, ΔP is the pressure difference across the membrane and L is the permeability coefficient.

For viscous flow the equation can be written as

$$J_v = \frac{n\pi r^4}{8\eta l}\Delta P \quad (2)$$

where n, r, η and l represent number of capillaries, radius of the capillaries in the membrane, viscosity of solution and length of the capillaries in the membrane respectively. Comparison of Eqs. (1) and (2) gives the following relationship.

$$L = \frac{n\pi r^4}{8\eta l} \quad (3)$$

The values of L have been calculated from the slope of a plot between J_v and ΔP and are recorded in Table I. Although it is expected that L should decrease by increasing the molecular weight of the solutes, yet this has not been found to be valid in the present case. It is obvious from Eq. (3) that

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L should decrease with an increase in η. This appears to be the cause for the unexpected variation of L with molecular weight of the solutes.

TABLE I

The values of various constants for different permeating species at 25°C. Concentration of all the permeating solutions was 0·1 M.

Permeating species	$L \times 10^8$ (Cm^5 dyn^{-1} sec^{-1})	$K_v \times 10^8$ (Cm^5 dyn^{-1} sec^{-1}) poise	$K_d \times 10^8$ (g. dyn^{-1})
Water	0·772	0·685	0·323
Acetamide	0·666	0·752	0.622
Urea	0·650	0·598	0·424
Glucose	0·731	0·710	0·835
Sucrose	0·605	0·635	0·731

In the case of diffusive flow the equation representing the transport of matter can be written as[11]

$$J_v = \frac{D\epsilon v}{RTl} \Delta P \qquad (4)$$

where D is the diffusion coefficient and ϵ is the fractional void volume. Comparing Eqs. (1) and (4) we get

$$L = \frac{D\epsilon v}{RTl} \qquad (5)$$

Separating the variables D, η and v from Eqs. (3) and (5) we can rewrite Eqs. as follows

$$L \times \eta = \frac{n\pi r^4}{8l} = K_v \text{ (say)} \qquad (6)$$

and

$$\frac{L}{Dv} = \frac{\epsilon}{RTl} = K_d \text{ (say)} \qquad (7)$$

If the flow through certain number of pores, n' is viscous and diffusive through the rest, the permeability coefficient can be written as[12,13].

$$\frac{L}{Dv} = \frac{n' \pi r^4}{8\eta l Dv} + \frac{\epsilon}{RTl} \qquad (8)$$

The role of pore size in the membranes becomes quite important when a permeating species enters the membrane. The three distinct cases are listed below:

(*i*) Pore size $\gg$ Mean free path of permeating molecules — Poiseulle's flow

(*ii*) Pore size $\ll$ Mean free path of permeating molecules — Knudsen flow

(*iii*) Pore size $\approx$ Mean free path of permeating molecules — Slip flow

A suitable explanation of the type of flow may be given in terms of Eqs. (6) and (7) in which variables are η, D and v. If the values of either K_d or K_v are constant, the flow will be either diffusive or viscous[14]. It is obvious from Table I that the values of neither K_d nor K_v are constant. This implies that the flow is neither diffusive nor viscous.

The data have been further utilized to examine whether the flow through n' pores is viscous and diffusive through the rest. A plot between L/Dv *vs.* $L/\eta D$ is a straight line with an intercept on L/Dv-axis in accordance with Eq. (8). It can be concluded that the flow through certain number of pores is diffusive and viscous through the rest. In other words, if is the case of slip flow.

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