Influence of Different Modes of Oxygenation of the Small Intestinal Mucosa in vitro on Glucose and Maltose Accumulation

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Abstract. Glucose accumulation by the everted sacs of the rat small intestine has been investigated during mucosal, serosal and bilateral oxygenations. The conditions are described under which active accumulation of glucose is provided by serosal but not only mucosal oxygenation.

It has been found that the active accumulation of glucose during the bilateral oxygenation is approximately equal to the sum of those during the serosal and mucosal oxygenations. The relative roles of the serosal and mucosal modes of oxygenation vary in the fed and fasting animals, as well as in the different segments of the small intestine. The results obtained may be explained by the hypothesis on the existence of two types of cell respiration — apical and basolateral.

Key words: Oxygenation — Small intestine — Transport — Membrane digestion — Cell respiration (apical and basolateral)

Introduction

The present knowledge of intestinal absorption, membrane hydrolysis and metabolic processes in the intestinal epithelium has mostly been gained due to an application of the technique of everted intestinal sacs of the small laboratory animals. This method proposed by Wilson and Wiseman (Wilson and Wiseman 1954; reviews: Wilson 1962; Wiseman 1964) is justly regarded as one of the most important methological achievements. It retains its significance up to the present time (reviews: Wilson 1962; Wiseman 1964; Parsons 1968; Ugolev 1968, 1974; Smyth 1974; Holdsworth and Sladen 1979; Levin 1979; and others). The suggestion to oxygenate mucosa from the apical surface requires a special consideration since under physiological conditions in vivo gas exchange between the epithelium and the blood capillaries occurs through the basal and lateral membranes of the enterocytes (review: Svanik and Lundgren 1977).

The remarkable idea of Wilson and Wiseman to make use of artificial mucosal oxygenation instead of the basal one is associated with the circumstance that in vitro the first one ensures a high level of active transport. While the serosal oxygenation fails to maintain active transport in an intestinal preparation in vitro,

apparently, because of insufficient gas exchange by diffusion between the serosal fluid and the basal surface of the enterocytes through serosal, muscular and submucosal layers. The above data have been confirmed by numerous authors and very recently by us (Ekkert et al. 1980; Ugolev et al. 1980). Moreover, we unexpectedly found that a combination of efficient mucosal and unefficient serosal oxygenations resulted in such high levels of glucose accumulation in the small intestine that have never been observed before.

This new phenomenon was initially viewed by us only as a technical achievement reached by improving oxygenation (Ugolev et al. 1980). However, an untraditional hypothesis was later suggested that enterocytes have two respiratory surfaces, a basolateral one and apical one (Ugolev 1980). The early experiments demonstrated that apical respiration is of no less importance for the maintenance of active transport than the basolateral one which is considered to be unique. The above hypothesis, however, raises some questions which have to be resolved before its acceptance. Thus, if the interpretation of the role of apical and basolateral respirations as the mechanisms providing O_2 supply for the supranuclear and subnuclear pools of mitochondria (Ugolev 1980), respectively, is correct, the efficiency of apical and basolateral oxygenations will be changed depending, on: the functional state, a kind of nutrients absorbed by the intestinal mucosa, location of the tested segment in the small intestine and its capacity for active transport. These and some other questions have been studied and are presented in this report.

Materials and Methods

Materials. All the reagents used were of analytical and research grade. The determination of glucose was made using glucosoxidase of Lvov mill of bacteriological preparations (USSR), peroxidase of Reanal (Hungary) and Serva (FRG), o-dianisidine of Sigma (USA) and a set of the Boehringer Mannheim (FRG).

Animals. The experiments were performed on 72 Wistar male rats weighing 180—200 g. The animals were placed into special cameras with natural lighting and were kept at 22 °C under laboratory conditions. Depending on the conditions of the experiments, fasting (20 hr) or fed animals were used. The latter were fed on a standard mixed ration ad libitum.

Preparation of modified everted sacs. After decapitation of a rat, the abdomen was opened by the middle section and the removed small intestine was washed two or three times with the Ringer solution cooled up to 0°C. Then accumulating mucosal preparations were prepared on cooling. They represented the everted and tight from both sides 4 cm intestinal segments (Ugolev et al. 1970). For the study of the proximal-distal gradients of glucose and maltose accumulations, the small intestine, except for the duodenum, was subdivided into 10 equal segments from which its preparations were then made.

Technique and variants of oxygenation. Water vapour-saturated gas (oxygen or nitrogen) was introduced into the serosal lumen of the preparations which were hermetically sealed from each side (Fig. 1). A manometer connected with the preparation of the small intestine made it possible to control the starting pressure of gas used in the serosal lumen of the preparation. In our experiments, gas was

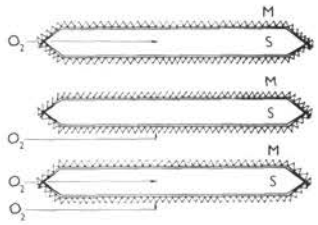

Fig. 1. Different modes of oxygenation of the small intestinal preparations. O_2-oxygenated surface; M — mucosal surface; S — serosal surface.

introduced into the serosal lumen of the everted sac under pressure from 10 to 520 mm H_2O. Thus, the internal lumen of the everted intestinal sacs, in some cases, contained oxygen and in others — nitrogen. The mucosal surface came into contact with the incubation solution saturated with either oxygen or nitrogen. The ready preparation was fastened to an anchor to prevent from floating. (Fig. 2).

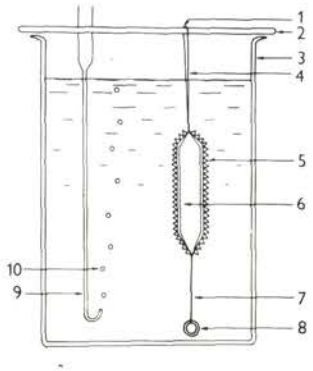

Fig. 2. Incubation of the small intestinal preparation. 1 — ligature, or a plastic ring to support the everted sac; 2 — glass tube; 3 — glass vessel; 4 — upper ligature; 5 — the mucosal surface of the everted sac; 6 — the serosal lumen, filled up either with oxygen, or nitrogen; 7 — lower ligature; 8 — weight; 9 — a tube for oxygenation or nitrogenation of the incubation medium; 10 — gas bubbles.

The following variants of the experiments were carried out: (1) nitrogen from the serosal and mucosal sides (bilateral nitrogenation); (2) oxygen from the serosal side, nitrogen from the mucosal side (serosal oxygenation); (3) nitrogen from the serosal side, oxygen from the mucosal side (mucosal oxygenation); (4) oxygen from both the serosal and mucosal sides (bilateral oxygenation). Thus, we had the possibility of investigating (1) accumulation dependent on serosal oxygenation; (2) accumulation dependent on mucosal oxygenation; (3) accumulation dependent on bilateral oxygenation. Such a model, as will be shown below, provides the opportunity for a more profound analysis of the mechanisms underlying the relationship between the accumulation of glucose in the small intestine and its oxygen supply.

Incubation of the preparations. The preparation of the small intestine was preincubated for 10 min in oxygenated Ringer solution at 0°C and was incubated in 10 mmol/l glucose or 5 mmol/l maltose Ringer

solutions (pH 7.4) at 37 °C to investigate the accumulation of free glucose and glucose released during the maltose hydrolysis. The incubation of the preparations lasted for 60 min since by this time a maximal concentration of transported substances was found.

Determination of glucose accumulation. Glucose accumulation in tissue fluid of the preparation was determined by a modified arsenic-molybdenic (Ugolev and Iezuitova 1969) and modified glucosoxidase methods (Dahlqvist 1964). The results were similar and were expressed in mmol/l as glucose concentration in tissue fluid for the time of incubation (Smyth 1974) and were statistically characterized (mean ± S. E.). The differences were statistically examined by using "U test" (Siegel 1956).

Results

The effect of oxygen pressure in the serosal lumen of the everted sac of the rat small intestine on glucose accumulation. We were unable to observe the glucose accumulation against an electrochemical gradient, when the introduction of oxygen under pressure 10 mm H_2O into the serosal lumen of the everted sac was combined with its incubation in 10 mmol/l nitrogen-saturated glucose solution. As shown in Fig. 3, an increase in initial pO_2 in the serosal lumen of the everted intestinal sac

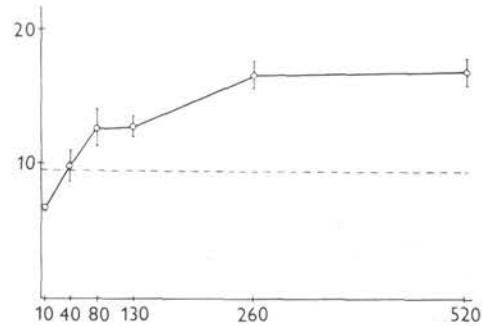

Fig. 3. Glucose accumulation by the tissue preparations of the rat small intestine in the fasting rats after 60 min incubation in 10 mmol/l glucose solution (saturated with N_2) depending on the initial oxygen pressure in the serosal lumen. Passive glucose accumulation is denoted by a dotted line. Abscissa — initial oxygen pressure in the serosal lumen (in mm H_2O). Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

from 10 mm to 520 mm H_20 results in an enhancement of glucose accumulation in the tissue preparations following 60 min incubation in 10 mmol/l nitrogen-saturated glucose solution. A maximal glucose accumulation was observed at initial pO_2 260 and 520 mm H_2O in the serosal lumen of the everted sac. Therefore, the accumulation of glucose by the tissues of the everted intestinal sacs depends at a certain interval on the starting pO_2 in the serosal lumen.

Fig. 4 shows that glucose accumulation is absent after the introduction of

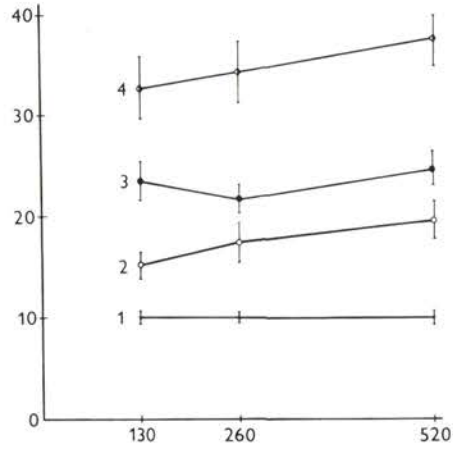

Fig. 4. Glucose accumulation by the tissue preparations of the rat small intestine in the fasting rats after 60 min incubation in 10 mmol/l glucose solution depending on the initial oxygen or nitrogen pressure in the serosal lumen (130, 260 and 520 mm H_2O) at diferent variants of oxygenation and nitrogenation. 1 — bilateral nitrogenation; 2 — serosal oxygenation; 3 — mucosal oxygenation; 4 — bilateral oxygenation. Abscissa — gas pressure in the serosal lumen. Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

nitrogen into the serosal lumen of the everted sac under pressure 130, 260 and 520 mm H_2O in mucosal nitrogenation. The glucose accumulation from 10 mmol/l glucose solution was slightly higher during the mucosal oxygenation than during the serosal oxygenation. During the bilateral oxygenation, the accumulation was maximal and essentially equal to the sum of the active components of glucose accumulation during the serosal and mucosal oxygenation and was significantly unaffected by an increase in pO_2 from 260 to 520 mm H_2O in the serosal lumen.

Considering the foregoing, the pressure 260 mm H_2O was used in all further experiments.

The effect of different modes of oxygenation on glucose accumulation in different segments of the small intestine in fasting rats. It has been established (reviews: Wilson 1962; Spencer 1964; Wiseman 1964; Deren 1968; Ugolev 1968; Holdsworth and Sladen 1979) that the absorption of nutrients varied considerably along the length of the small intestine. We confirmed (Fig. 5) that glucose accumulation which is well expressed in the jejunum and proximal ileum, sharply decreases in the caudal direction and is absent from the distal ileum. These results obtained during the mucosal oxygenation of the everted intestinal sacs are in agreement with previous data (reviews: Spencer 1964; Ugolev 1968; Scientific basis of gastroenterology, 1979).

The question arises what is the distribution of glucose accumulation along the small intestine during the serosal, or the bilateral oxygenation. As it can be seen from the same Fig. 5, there are certain differences in the proximal-distal gradients

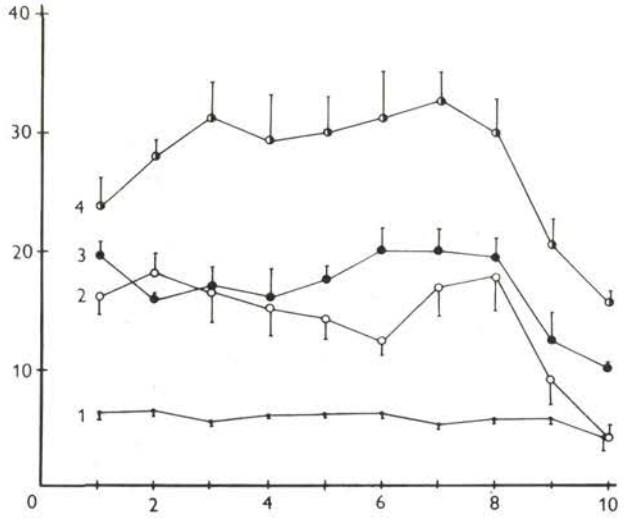

Fig. 5. The proximal-distal gradient of glucose accumulation by the tissue preparations of the small intestine in the fasting rats after 60 min incubation in 10 mmol/l glucose solution (initial gas pressure in the serosal lumen 260 mm H_2O). 1 — bilateral nitrogenation; 2 — serosal oxygenation; 3 — mucosal oxygenation; 4 — bilateral oxygenation. Abscissa — the intestinal segments from beginning of the jejunum up to the end of the ileum. Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

of the glucose accumulation during the serosal and mucosal oxygenations. In particular, in both instances, the glucose accumulation is identical in the most proximal segment of the jejunum with that in the middle ileum. At the same time, in the majority of intestinal segments, the glucose accumulation dependent on the mucosal oxygenation is somewhat higher.

Of particular importance is the circumstance that during the bilateral oxygenation there is a pronounced maximum of accumulation in the distal jejunum and the proximal ileum, as well as a significant accumulation in the distal ileum. Thus, the characterization of the proximal-distal gradients of glucose accumulation obtained by three modes of oxygenation in vitro differs from that described in literature.

The reasons for these differences will be considered below on the basis of a comparison of the proximal-distal gradients of the glucose accumulation in the

fed and the fasting animals as well as those of the accumulation of free glucose and glucose released during maltose hydrolysis.

The effect of different modes of oxygenation on the accumulation of glucose released during the maltose hydrolysis in different segments of the small intestine in fasting rats. The relationship between the absorption of free glucose, on the one hand, and that of maltose, on the other hand, has been the subject of numerous studies. It has been found that in various mammals (small laboratory animals and human subjects were more thoroughly investigated) both in situ and in vitro the maltose uptake is near to or exceeds that of free glucose (Chain et al. 1960; Parsons and Prichard 1971; Matthews et al. 1968; Ugolev 1968, 1974; Malathi et al. 1973; and others).

The accumulation of glucose released from the maltose hydrolysis (enzyme-dependent transport) is characterized by definite proximal-distal gradients and depends on the concentration of absorbed substrate. For example, at low substrate concentrations used in the present study as well, the transport of monomers may be equal or higher if compared with that of oligomers (Matthews et al. 1968).

The results of our studies of enzyme-dependent accumulation of glucose, namely, glucose formed during the maltose hydrolysis are presented in Fig. 6. As it

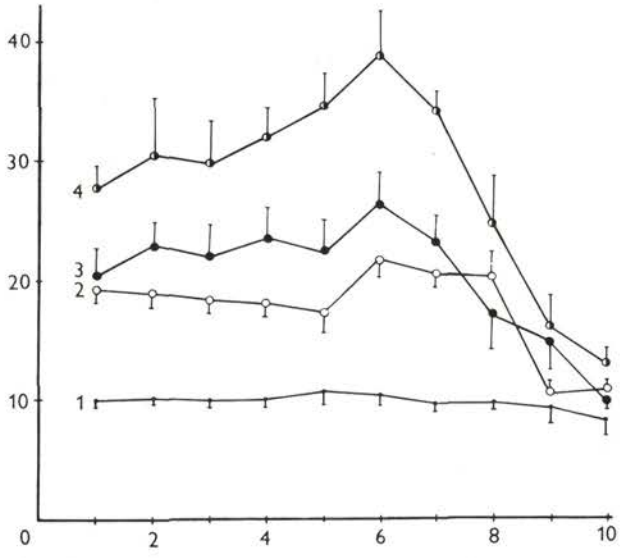

Fig. 6. The proximal-distal gradient of accumulation of maltose hydrolysis-released glucose by the tissue preparations of the small intestine in the fasting rats after 60 min incubation in 5 mmol/l maltose solution (initial gas pressure in the serosal lumen 260 mm H_2O). 1 — bilateral nitrogenation; 2 — serosal oxygenation; 3 — mucosal oxygenation; 4 — bilateral oxygenation. Abscissa — intestinal segments from the beginning of the jejunum up to the end of the ileum. Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

can be seen, the levels of glucose accumulation in the first four segments are similar. No significant difference was found between the serosal and the mucosal oxygenations. In more distal segments, the mucosal oxygenation resulted in a slight predominance of the enzyme-dependent accumulation of glucose. As in the case with free glucose, a decrease in the accumulation of glucose released from the maltose hydrolysis was observed in the caudal segment of the intestine. In the 6th and 10th segments, the accumulation of enzyme-dependent glucose was significantly higher during the mucosal oxygenation than that during the serosal one.

The active accumulation (accumulation against gradient) of glucose released from the maltose hydrolysis during bilateral oxygenation is close to the sum of

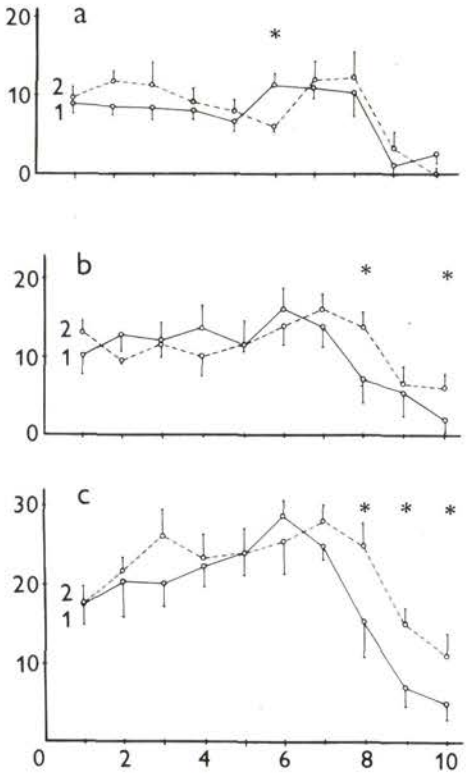

Fig. 7. The proximal-distal gradient of active accumulation of free glucose and maltose hydrolysis-released glucose by the tissue preparations of the small intestine in the fasting rats after 60 min incubation in equimolar glucose and maltose solutions (10 and 5 mmol/l, respectively) initial gas pressure in the serosal lumen 260 mm H_2O). a — serosal oxygenation, b — mucosal oxygenation, c — bilateral oxygenation. 1 — active accumulation of free glucose; 2 — active accumulation of enzyme-dependent glucose. Abscissa — intestinal segments from the beginning of the jejunum up to the end of the ileum. Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

the two glucose influxes observed during the mucosal and serosal oxygenations (Fig. 6).

A comparison of the accumulation of free glucose and glucose released from the maltose hydrolysis in different segments of the small intestine in fasting rats. As it can be seen in Fig. 7 (a, b, c) during serosal oxygenation, the active accumulation

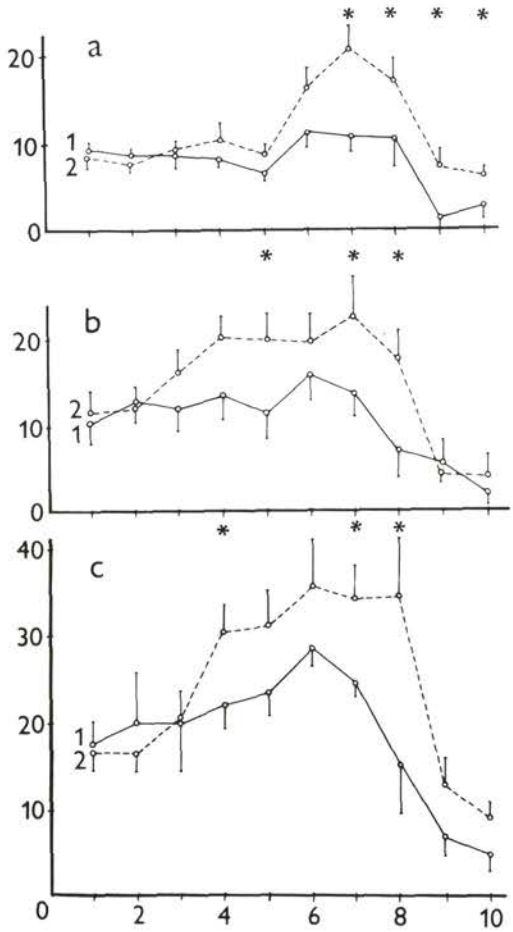

Fig. 8. The proximal-distal gradient of active accumulation of free glucose by the tissue preparations of the small intestine in the fed and fasting rats after 60 min incubation in 10 mmol/l glucose solution (initial gas pressure in the serosal lumen 260 mm H_2O). Active accumulation of glucose: a — serosal oxygenation, b — mucosal oxygenation and c — bilateral oxygenation. 1 — in the fasting rats; 2 — in the fed rats. Abscissa — intestinal segments from the beginning of the jejunum up to the end of the ileum. Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

rates of free and enzyme-dependent glucose are almost the same in most segments of the small intestine. Only in the 6th segment, the active accumulation of free glucose in significantly higher if compared with that of the glucose formed during the maltose hydrolysis. During mucosal oxygenation the enzyme-dependent glucose active accumulation is slightly higher in the caudal segments than that of free glucose. During the bilateral oxygenation this difference becomes more pronounced.

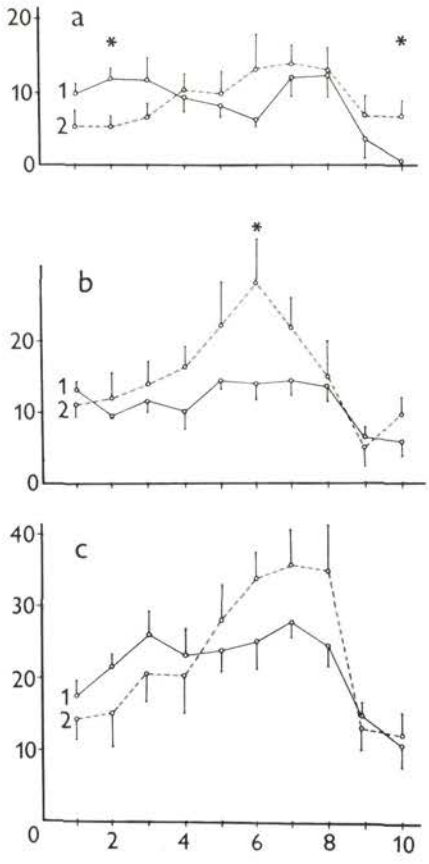

Fig. 9. The proximal-distal gradient of active accumulation of enzyme-dependent glucose by the tissue preparations of the small intestine in the fasting and fed rats after 60 min incubation in 5 mmol/l, maltose solution (initial gas pressure in the serosal lumen 260 mm H_2O). Active accumulation of maltose hydrolysis-released glucose: a — serosal oxygenation, b — mucosal oxygenation and c — bilateral oxygenation. 1 — in the fasting rats; 2 — in the fed rats. Abscissa — intestinal segments from the beginning of the jejunum up to the end of the ileum. Ordinate — glucose concentration in the tissue preparation of the small intestine (in mmol/l). Mean ± SE, n = 6.

Accumulation of free and enzyme-dependent glucose in fasting and fed rats. The stimulation of membrane hydrolysis and transport following a meal is documented (De Laey 1967). In our experiments, we attempted to examine the distribution of postprandial effect on the accumulation of glucose dependent on mucosal and bilateral oxygenation.

When comparing the levels of passive accumulation of free glucose during the bilateral nitrogenation in the fasting and fed rats no differences were revealed in all the 10 tested segments of the small intestine. However, it should be noted, that under the same conditions, the enzyme-dependent accumulation of glucose in the jejunum and the proximal ileum was more enhanced in the fed than in the fasting animals.

During the serosal oxygenation (Fig. 8), a preliminary food load had insignificant effect on the active accumulation of free glucose in the jejunum. However, in the 7th—10th intestinal segments corresponding to the middle and distal ileum, a considerable increase in the oxygen-dependent active accumulation of free glucose was observed in the fed animals. It is of interest, that this region was termed by Dowling and Booth (1967) as a reserve zone.

A significant enhancement in the active accumulation of free glucose was revealed from the 4th to the 8th intestinal segments in the fed animals during the mucosal and bilateral oxygenations (Fig. 8, c). Thus, during bilateral oxygenation, the postprandial functional topography of the small intestine changed due to a high level of the active accumulation of free glucose in the distal jejunum and proximal ileum.

The postprandial active accumulation of glucose released from the maltose hydrolysis reminds, to a certain extent, of the active accumulation of free glucose. The effect of a preliminary feeding was distinctly manifested during the mucosal and bilateral oxygenation (Fig. 9, a, b, c). It is interesting to notice that in the fed rats a maximal active accumulation of enzyme-dependent glucose is localized in the 5th—8th segments of the small intestine.

Discussion

Different modes of oxygenation and transport function of the enterocytes. The attempts to compare the efficiency of different modes of oxygenation of the small intestinal preparations in vitro have been undertaken earlier by many investigators, and Wiseman and Wilson were the first (Wilson and Wiseman 1954; reviews: Wilson 1962; Wiseman 1964). However, these attempts were met with great difficulties, since comparisons were essentially made not only with different types of oxygenation but also with various preparations. In fact, the experiments were carried out using the everted sacs of the small intestine, its stripes and rings as well. It is clear that various preparations possess different properties. Thus, for example,

absorption in the everted sacs may be described by four fluxes (two serosal and two mucosal), absorption by the small intestinal rings requires the consideration of six fluxes (along with the above mentioned, two lateral fluxes have to be considered etc.) (reviews: Parsons 1968; Ugolev et al. 1970; Soergel and Hofmann 1972; Smyth 1974; Levin 1979; Holdsworth and Sladen 1979 and others).

The comparison of different modes of oxygenation in our experiments has two advantages: (1) all the variants of the experiments were performed with identical preparations; (2) the results obtained using the above described intestinal preparations can be more easily interpreted since the accumulation of substances is determined only by two mucosal fluxes: influx and efflux. This is very important because the steady-state concentrations of accumulated glucose in our experimental conditions depend on a passive efflux of glucose and its active influx. Thus, the tissue concentration of glucose is a simple index of the functioning of glucose pumps.

Our findings led consistently to the conclusion that the results obtained for the last two decades using the everted sacs of the small intestine, although they still preserve their importance, should now be interpreted as an intestinal absorption under hypoxic conditions.

Really, a combination of serosal oxygenation with the mucosal one results in a significant increase in the level of glucose accumulation. However, the relative role of each mode of oxygenation for the net effect appears to vary, as shown by the experiments, and requires further investigations.

We have found that the relative role of serosal and mucosal oxygenations depends on the location of a tested segment along the small intestine, the functional state of the organism and, finally, the properties of the substrate to be absorbed. Thus, for example, the glucose accumulation which was rejected in the distal segments of the small intestine by earlier studies is manifested during the bilateral oxygenation. This testifies to the importance of further conclusions which may be drawn from the bilateral oxygenation.

However, great difficulties and unexpected inferences arise when we try to understand the mechanisms underlying the observed phenomena, in particular, that the active accumulation of glucose during the bilateral oxygenation is equal to the sum of those during the serosal and mucosal oxygenations. In physiology, pharmacology and molecular biology, beginning from the classic studies by Sherrington (1906) similar phenomena have been used to interpret as availability of two distinct mechanisms. This explanation, attractive by its simplicity, has been proposed by us to account for the relationship between the mucosal and serosal cell oxygenations (Ugolev 1980, 1981). This approach has ultimately led to the unexpected conclusion that at least enterocytes and, possibly, other polarized cells have two types of respiration (basolateral and apical) rather than one, as previously suggested.

Two types of cell respiration and interpretation of described phenomena (Fig. 10). According to the classic concepts gas exchange between a cell and blood capillaries occurs through the basal and lateral surfaces of enterocytes due to the diffusion of O_2 and CO_2 down a concentration gradient.

According to these concepts $Na^+ - K^+$-ATPase of the basolateral membranes pumps Na^+ out of the cells and K^+ into the cells, creating ionic gradients. The energy of the latter is utilized for active, in particular, Na^+-dependent transport of glucose, amino acids and other solutes through the apical membranes of the enterocytes (secondary energization). ATP is required for the functioning of basolateral pumps produced by the mitochondria localized in close proximity, that is, basolaterally. From this viewpoint, the efficiency of the basolateral respiration is obvious (reviews: Alvarado 1976; Atkinson 1977; Kaback et al. 1978; Kinne 1979; Schultz 1979; Ullrich et al. 1979; West 1980; and others).

This model, now widely accepted, is very likely adequate, for the cells with basal localization of mitochondria are the major consumers of O_2 (reviews: Atkinson 1977; Kinne 1979; Kriz et al. 1979; Ullrich et al. 1979; and others).

The hypothesis of apical respiration seems to be unnecessary for the cells only with the basal localization of mitochondria.

However, in the enterocytes, in the cells of different segments of the renal tubules and in some other cells, along with the basal pool of mitochondria there exists their supranuclear, or apical pool. For such cells, the generally accepted hypothesis encoutered with serious problems. First of all, O_2 diffusion from the capillaries to the apical part of the cells is much less effective because of a long pathway. The supranuclear and subnuclear space are separated to a certain extent by a nucleus which occupies almost the entire cross section of the cells. Moreover.

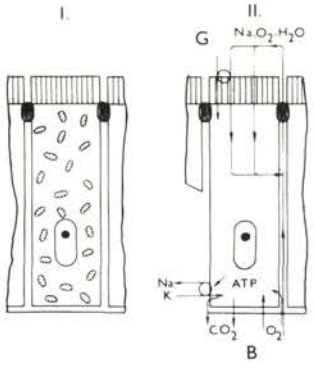

Fig. 10. Schematic representation of the hypothesis on the apical and basolateral cell respiration (after Ugolev 1980). 1 — distribution of mitochondria in the enterocyte; 2 — major fluxes of some substances in the enterocyte and other structures of the small intestine. G — glucose (or amino acids), B — blood.

most investigators agree that in the enterocyte, during absorption of food substances, there is a liquid flow directed from the apical to the basolateral cell surface (Ullrich et al. 1979; Gruzdkov et al. 1981). This reduces the efficiency of O_2 diffusion from the basolateral surface to the apical one, since the rate of transfer of a particular substance is, eventually, equal to the sum of its diffusion rate and the rate of transfer of this substance with a water flow.

However, it should be noted that O_2 influx from the apical surface of the cells may provide a sufficient oxygenation for the mitochondria located in the supranuclear region. The localization of mitochondria not only in a subnuclear but also in a supranuclear region favours the existence of two complexes ensuring the energization of cell functions (Fig. 10).

If to postulate the availability of a physiological mechanism ensuring apical oxygenation, then effective apical energization will become more understandable. A capillary ultrafiltrate which is reabsorbed in the zone of the apical surface of the enterocytes has been suggested as a source of O_2 for apical respiration (Ugolev 1980). An important, though indirect, argument for this suggestion is the recently found Na^+ microcirculation in the intestinal mucosa (review: Alvarado 1976). In developing the hypothesis, we postulated that the microcirculation of the fluid entering from the capillaries to be absorbed by brush border surface provides a simultaneous supply for the transport systems of the enterocytes with O_2 needed for primary energization and with Na^+ required for secondary energization. It has been demonstrated by Ugolev and others in the chronic experiments on healthy rats, that there occurs an intensive gas exchange between the lumen of the small intestine and blood. In particular, O_2-saturated saline loses about 50—80% of oxygen when passing through the isolated 15 cm segment of the rat small intestine (at the perfusion rate of 0.5 ml/min and volume of perfused segment — 0.5—0.8 ml). It has been established under the same conditions that perfusion with nitrogen-saturated and oxygen-free saline is followed by O_2 influx into the small intestinal lumen (after Godetsky et al. 1981).

The hypothesis of apical and basolateral respiration for explaining the different characteristics of epithelial transport. The hypothesis on two types of respiration has recently been confirmed by a new convincing evidence. Bohlen (1980) using O_2 microelectrode technique has shown that pO_2 on the apical mucosal surface at rest is maintained at the level of about 40 mm Hg. During glucose absorption, an enhancement in microcirculation and reduction in pO_2 was simultaneously observed on the apical surface.

Godetsky et al. (1981) have investigated O_2 uptake by the isolated stripes of the frog small intestine. Both pathways of O_2 consumption (apical and basolateral) have been demonstrated by means of the O_2 microelectrode technique. It has also been shown that during glucose absorption, an increase in the apical O_2 uptake

takes place, which may be prevented by an addition of phlorizin into the incubation medium. This may be considered as a direct proof of the connection between apical respiration and glucose accumulation. These data are in good agreement with the results presented.

At first sight, the data considered in this paper may appear to be at variance with the presently accepted model of energization of glucose transport. However, there are strong arguments in favour of participation in glucose transport of an apical mechanism of primary energization along with a basolateral one (reviews: Kinne 1979; Ullrich et al. 1979; Ugolev 1981). This is consistent with the experimental data on the existence of two glucose pumps — apical and basolateral (Esposito et al. 1972; and others).

Thus, the hypothesis on two types of cell respiration — basolateral and apical — in the enterocyte may account for some unexpected findings revealed by us in studying the effects of different modes of oxygenation on the accumulation of glucose. According to this hypothesis gas exchange through the basolateral surface of the cells provides oxygenation for a subnuclear pool of mitochondria and gas exchange through the apical surface ensures oxygenation for a supranuclear pool of mitochondria. Our hypothesis can readily explain the fact that the efficiency of bilateral oxygenation is approximately equal to the sum of those of mucosal and serosal oxygenations. However, in terms of the classic hypothesis, the interpretation of this phenomenon presents a formidable difficulty.

The development of the concepts on two types of cell respiration could be important for a better understanding of the regularities of different cell and organ functions in normal and pathological states, as well as for the elucidation of the evolutionary aspects of cell respiration.

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Received August 12, 1981/Accepted November 18, 1981