THE SURFACE AREA OF THE INTESTINAL MUCOSA IN THE RAT AND IN THE CAT

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Within recent times there has been a renewal of interest in problems of absorption from the intestinal tract. A factor of prime importance in this process is the area of the mucous membrane across which absorption takes place. Unfortunately, this fundamental anatomical aspect seems to have received but scant attention.

The early attempts to estimate the intestinal mucosal area did not give consistent results. Warren (1939) has reviewed the work of the past in detail, and tabulated the more important results. He then, with improved technique and method of calculation, found the mucosal area at different levels in the small intestine of one dog.

However, there are still no results for the rat and the cat, the two animals most frequently used for experimental work on absorption (Cori, 1925; Verzár & McDougall, 1936). It seemed worth while, therefore, to obtain data concerning the intestinal absorbing surfaces in these two animals.

METHOD

Modifications were introduced into the experimental technique of Warren (1939) with the object of ensuring rapid fixation of the gut under standard conditions of distension.

The animal, rat or cat, was anaesthetized and the abdomen widely opened. A cannula, directed caudad, was tied into the proximal jejunum and an opening made in the ileum just craniad to the large intestine. The whole small intestine was then washed free from faecal matter by a stream of Ringer solution at 38° C. Thereafter, a second cannula, directed craniad, was tied into the intestine through the opening in the ileum. Midway between the two cannulae a piece of intestine was cut completely out and the remaining portions of ileum and jejunum connected by tying in a T piece of glass tubing. The length of the upright limb of this T piece determined the head of pressure to which all portions of the gut were uniformly exposed. The gut was then freed from the mesentery, and the cannulae with attached intestine transferred to a large flat dish. Ringer solution was once more run through the gut, entering by both cannulae and leaving by the vertical limb of the T piece. The Ringer solution was gradually replaced by fixative to prevent localized spasm of the gut musculature. Finally, full-strength fixative was poured over the peritoneal surface of the gut. As fixative a solution of picric acid in dioxan gave the most satisfactory results (Carleton, 1938). The method employed in fixation is shown in Fig. 1.

When fixation was complete, straight portions of jejunum and of ileum, roughly 6 cm. in length, were cut off. Each of these pieces was further divided into three, a central segment approximately 4 cm. long, and two end portions (Fig. 2).

In a few cases the large intestine was fixed under the same standard conditions, the intermediate colon being chosen for study.

After embedding in paraffin, transverse sections were cut from end portions and longitudinal sections from the central segment at its greatest diameter (Fig. 2). The sections were stained.

To find the area of the mucous membrane from these histological preparations the following formula, recommended by Warren (1939), was used:

$$\frac{EA}{SA}=\frac{MC}{SC}+\frac{ML}{SL}-1,$$

where EA is the unknown, the mucosal area,
SA is the serosal area,
MC is the mucosal circumference,
SC is the serosal circumference,
ML is the mucosal length,
SL is the serosal length.

To make measurement possible, the sections were projected on to large sheets of white paper at known magnification. The mucosal and serosal outlines were drawn in pencil and then measured by a rotometer calibrated in centimetres. The values thus obtained, after due allowance for magnification, were inserted in the formula and the unknown EA calculated.

RESULTS

Histological appearances. In the same animal the final microscopic preparations showed no significant difference between the diameter of the jejunum and of the ileum. In the rat the average diameter was 0·5 cm., in the cat 1·1 cm. However, to simple inspection even, it was obvious that the villi are more numerous in the cranial than in the caudal region of the small intestine. In the rat the villi are leaf-shaped, the long axis of the villous leaves running at right angles to the length of the gut, while in the cat the villi are finger-shaped.

The area of the mucous membrane. Measurements were carried out on eight rats and on four cats. Table 1 gives the mean figures for the mucosal area

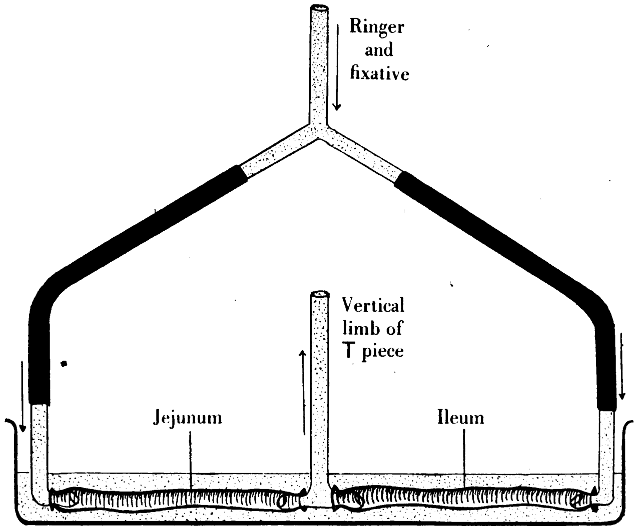

Fig. 1. The arrangement of gut segments and cannulae to ensure fixation of the gut under standard conditions. In practice, the gut segments were relatively much longer.

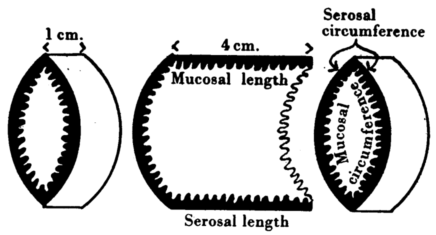

Fig. 2. The figure shows the treatment of the gut in order to find the measurements necessary to calculate the area of the mucous membrane.

per centimetre serosal length of gut in the fixed state.

Table 1. *Mean figures for mucosal area. Comparison between surface area of the mucosa in jejunum, ileum and colon per centimetre length of gut*

(Sq. cm./1 cm. serosal length)

	Jejunum	Ileum	Colon
Rat	8·5	5·1	2·2
Cat	49·5	35·5	5·6

The figures for the area of the mucous membrane in Table 1 are of necessity partially dependent on the diameter of the gut. The influence of gut diameter can be eliminated by finding the ratio $\frac{\text{mucosal area}}{\text{serosal area}}$. This ratio gives an indication of the degree of villous development, being $\frac{1}{1}$ in the absence of villi and increasing in magnitude with increasing villous development. Table 2 gives the ratio $\frac{\text{mucosal area}}{\text{serosal area}}$ for the jejunum, ileum and colon in the rat and cat.

Table 2. *The ratio* $\frac{\textit{mucosal area}}{\textit{serosal area}}$ *in jejunum, ileum and colon. The larger this ratio, the greater is the villous development*

	Jejunum	Ileum	Colon
Rat	$\frac{6}{1}$	$\frac{4}{1}$	$\frac{1}{1}$
Cat	$\frac{15}{1}$	$\frac{12}{1}$	$\frac{1}{1}$

DISCUSSION

Absolute values. The absolute values in the present work are obviously valid only for gut subjected to the procedure here described. Nevertheless, it is interesting that Warren (1939) found the mucosal area per centimetre serosal length to be 54 sq. cm. in the jejunum of the dog and 38 sq. cm. in the mid ileum. These values are remarkably close to the corresponding figures for the cat in this work. However, in the dog, Warren found that the ratio $\frac{\text{mucosal area}}{\text{serosal area}}$ was $\frac{8\cdot5}{1}$ in the jejunum and $\frac{6\cdot8}{1}$ in the ileum. These ratios are smaller than those in the cat although greater than those in the rat.

Relative values. Every care was taken to ensure that the whole small intestine in each animal reacted uniformly throughout its length to the manipulations of fixation and embedding. Distortions of absolute values should then cancel out in making comparisons between different portions of the gut in the same animal, and the comparisons should be valid for the living state.

It would appear that the mucosal surface of the jejunum per unit length, in both rats and cats, is roughly $1\frac{1}{2}$ times as great as the mucosal surface of the ileum. This must be attributed, in both animals, to greater villous development in the jejunum since the diameter of the small intestine remained uniform throughout its length.

If we assume that the intestines of rats and cats retained their relative dimensions throughout the processes of fixation and embedding, then it is justifiable to compare the small intestine of the rat with that of the cat.

Villous development as a whole must be more marked in the small intestine of the cat than of the rat. The mucosal area, per sq. cm. serosal area, was roughly three times as great in the cat.

It was noted that the post-mortem lengths of the small intestine, in both rats and cats, were in the neighbourhood of 100 cm. Assuming a uniform decrease in mucosal area from cranial to caudal end of the small intestine, it is possible to find the ratio

$$\frac{\text{total mucosal area of small intestine in the rat}}{\text{total mucosal area of small intestine in the cat}}$$

from the figures in Table 1. The average mucosal area, per centimetre length, is 6·8 sq. cm. in the rat and 42·5 sq. cm. in the cat. This gives a ratio of $\frac{1}{6\cdot 3}$, implying that the mucosal area of the small intestine of the cat is more than 6 times the mucosal area of the small intestine in the rat.

The rats used in this work had an average weight of 295 g., the cats an average weight of 1950 g. The ratio $\frac{\text{body weight of rats}}{\text{body weight of cats}}$ is therefore $\frac{1}{6\cdot 6}$.

Without stressing unduly, in view of the assumptions involved, the close agreement between these two ratios, it is yet obvious that the mucosal surface of the small intestine has an intimate relationship to the body weight even when comparing two such different creatures as the rat and the cat. This relationship, if expressed in the form

$$\frac{\text{mucosal surface of small intestine}}{\text{body weight}}$$

is a constant, immediately brings to mind a similar generalization by Cori (1925). In his case the result was perhaps not so unexpected since he worked only on rats of different weights. From the quantities of various sugars absorbed from the intestine he concluded that $\frac{\text{intestinal absorbing surface}}{\text{body weight}}$ is a constant. Thus, purely morphological observations in the present work suggest that an important generalization may be still further extended.

SUMMARY

1. The cranial and caudal ends of the small intestine in rats and in cats were fixed histologically under standard conditions. The gut was then embedded and sectioned.

2. From measurements made of transverse and longitudinal sections of jejunum and ileum the relative surface areas of the mucous membrane were calculated.

3. Both in the rat and cat, the area of the mucous membrane, per unit length of gut, is greater in the jejunum than in the ileum. This is due to the greater villous development in the jejunum.

4. The mucosal area, per unit serosal area, is greater in the cat than in the rat.

5. The ratio

$$\frac{\text{mucosal area of the entire small intestine}}{\text{body weight}}$$

is similar in the rat and cat.

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