Some important differences were encountered between the behaviour of rat and guinea-pig ileum, and the results cannot easily be explained in terms of the model applied to the guinea-pig. Replacement of the serosal solution with potassium abolished the short-circuit current, indicating that the potassium diffusion potential is equal to the sum of the sodium diffusion potential and the potential of the electrogenic sodium pump. This could imply that the difference in the permeabilities of the tissue for the two ions is greater than in the guinea-pig, or that the pump is less active in the rat. Neither of these explanations could account for the maintenance of an almost normal current when potassium bathes the mucosal face. This latter result suggests the existence of a mucosally-directed electrogenic sodium pump, as confirmed by the large inversion of polarity when the mucosal face is bathed with choline. Thus the serosally-orientated electrogenic pump appears to be less active in the rat and there probably exists an electrogenic mucosally-orientated sodium pump. Finally, the reduction when sulphate is placed in the serosal chamber suggests the participation of a chloride diffusion potential, in accordance with the low permeability of the rat intestine to sulphate[7], or possibly the existence of an electrogenic chloride secretion mechanism in the luminal membrane, analogous to that of the jejunum[9], which would be inhibited when sulphate bathes the serosa. However, the other observations suggest that a cation rather than an anion is extruded electrogenically across the brush border.

Ouabain partially inhibits the serosally-orientated electrogenic pump in the rat, a species known to be rather insensitive to cardiac glycosides[10]. Indeed, the fact that ouabain affects the short-circuit current without influencing Na^+-dependent amino-acid transport[11] constitutes evidence in favour of the existence of a second sodium pump, independent of a ouabain-sensitive ATPase, as argued elsewhere[11].

When potassium + ouabain bathe the serosal face of the tissue, there is an important inversion of polarity, probably as a consequence of the high permeability to potassium, coupled with a partial inhibition of the Na^+-K^+-ATPase pump. Unexpectedly, there is no increase in the inversed polarity, as occurred in the guinea-pig, when ouabain is added to the choline medium in the serosal chamber.

Finally, there is an enormous inversion of polarity when the mucosa is bathed with choline and ouabain, and the sodium is retained at the serosa. This intriguing result, which was confirmed repeatedly, often using paired tissues, signifies that under certain conditions, ouabain interacts directly with the luminal face of the mucosa, though not by inhibiting a Na^+-K^+-ATPase-dependent ion flux (since in this case, the inverted potential would be decreased, not increased). One possibility is that an electrogenic recapture of sodium ions is inhibited. It is known that the coupled entry of sodium ions and amino-acids or monosaccharides is an electrogenic process[12,13], and there is some evidence, in certain species[14], that energy resulting from the action of Na^+-K^+-ATPase might be involved in the process. The fact that there is no analogous occurrence when potassium + ouabain bathe the mucosal face is consistent with this explanation, since the events surmised would probably be inhibited by potassium[15]. On the other hand, the effect of the mucosal ouabain is so huge that a purely physical explanation, such as a change in the permeability characteristics of the junction complexes, must be considered. Evidently, the influence of ouabain on the luminal membrane of the rat intestinal mucosa would repay further study.

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Capillary Lengths and Areas, and Intercapillary Distances in Tissue Near the Human Knee[1]

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Summary. Quantitative stereological electron microscopy has been used to investigate the capillary lengths, surface areas and intercapillary distances in the tissues around the human knee, the synovial membrane, synovial capsule, fat and tendon. The vascularity of these regions was much less than in other areas of the body, especially muscle.

The principles of stereology[2-4] have not yet been extensively applied to describing the quantitative morphology of blood capillaries. Such applications are essential if the findings of physiology are to be integrated with those of morphology in order to comprehend, at the fine structural level, the detailed functioning of the various capillary-types and the tissues they serve.

A start has been made in this direction. It has been shown[5] that the lengths, widths and depths of the close junctions in dog skeletal muscle allow one to calculate the capillary filtration and diffusion coefficients with very good agreement with those found by experiment; the vesicular numbers, etc., give good agreement with experimental results, using a Brownian-motion model. With the fenestrated capillaries of the cat jejunum[6], it was found that the filtration and diffusion coefficients so calculated were many orders of magnitude greater than those found by experiment. This indicated that these capillaries correspond to the tunnel-capillaries of INTAGLIETTA and DE PLOMB[7]; the continuous capillaries of the muscle are tube-capillaries, where the permeability is controlled by the endothelium. In tunnel-capillaries the endothelium has no influence on permeability, except for cells and the largest macromolecules: it is the interstitial connective

	Synovial membrane		Synovial capsule		Fat		Tendon	
Capillaries/cm² of sections [a]	7040	(2350)	3330	(1620)	7640	(2450)	4320	(1820)
Length of capillaries (cm/cm³)	14100	(4700)	6670	(3230)	15300	(4900)	8470	(3648)
Surface area [b] of capillaries (cm²/cm³)	22.5	(10.9)	10.7	(6.38)	24.4	(11.6)	13.5	(7.52)
'Intercapillary distance' (μm) [c]	119	(68.8)	173	(121)	114	(64.7)	154	(101)

[a] The standard errors of the means are in brackets; $n = 40$. [b] Using the lengths $\times 2/\Pi \times$ the mean measured luminal circumference (25.1 (8.85) μm[5,6]). [c] Using (1/capillaries per cm²) as described elsewhere[5,6].

tissue which controls the passage of all molecules smaller than these. Using observational data and the tunnel-capillary model[7], it is indeed possible to predict quite accurately the capillary filtration coefficient[6]. When continuous capillaries are injured, it can be shown[8] that the numerous open junctions would allow so much permeation of the endothelium that these vessels temporarily become tunnel-capillaries, reverting to tube-capillaries once the junctions reclose, but with an enhanced permeability to macromolecules for a long time – probably due to the formation of vacuoles in the endothelium.

These quantitative studies, however, refer only to a few sites in a few species. Some colleagues[9] have been trying to predict the occurrence of 'the bends' after diving, i.e. the release of small bubbles of air in certain tissues. It would appear that the tissues of the knee are one of the most important sites where this occurs[10]. Unfortunately, apart from the human ventricle[11], no quantitative studies appear to have been made in man; while numerous studies have been made in the muscles of other

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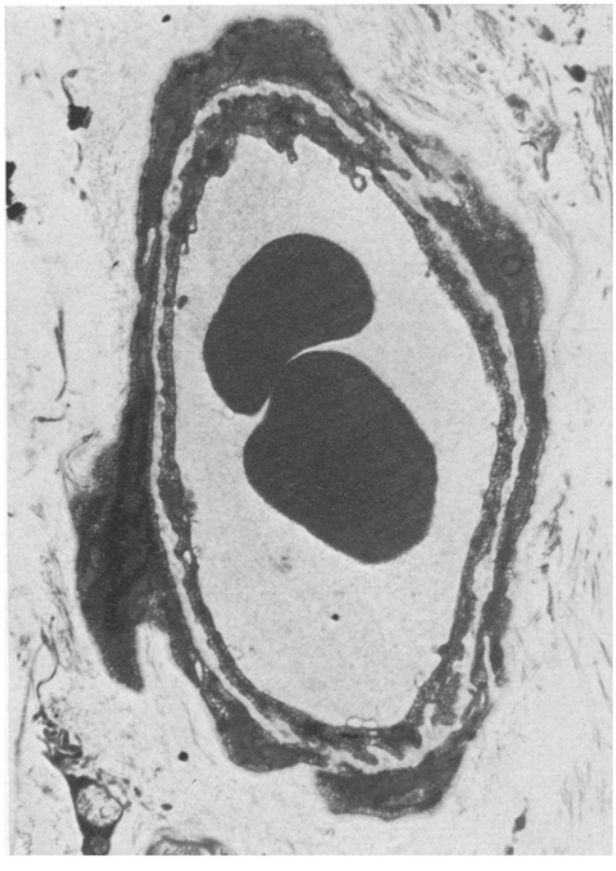

Fig. 1. A capillary in the synovial capsule, showing the normal features as seen in other mammals. × 8000.

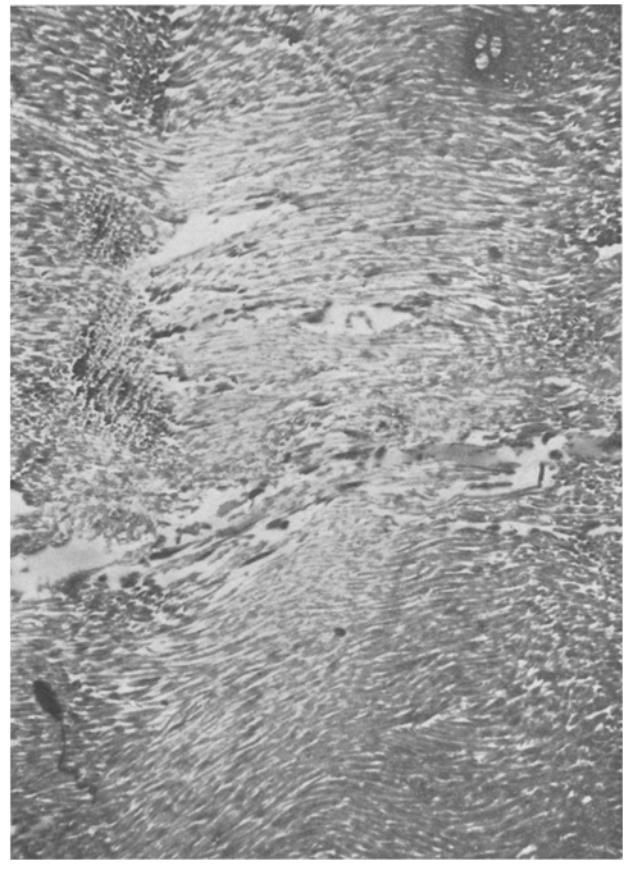

Fig. 2. A an expanse of collagen fibres in the tendon; no capillaries are visible. × 3000.

species[11–13], none have been made of the tissues near joints. It was therefore necessary to study some quantitative aspects of the capillaries of tissues near the human knee, in order to provide the data necessary for the model for understanding and predicting the occurrence of bends[9].

Specimens were obtained from 5 healthy young men, who had to have menisectomies due to recent sports-injuries. The tissues studied were: the deeper layers of the synovial membrane, the synovial capsule, fat, and tendon. They were processed by the normal methods[5,6] used for quantitative stereological electron microscopical morphology of capillaries. (These include attention to the colloidal osmotic pressure of the fixative and the standardization of the magnifications.) 4 separate, random blocks were taken from each piece of tissue and only 1 random section of each examined. Separated, random micrographs were made of each section with total mean areas of 3190 (SE 81.5) μm^2.

The results are shown in the Table and illustrated in the Figures. Poissonian distributions were used to determine the standard errors. The surface areas were calculated using the mean measured luminal circumference $\times$the lengths, adjusted as described elsewhere[5,6]. The intercapillary distances[5,6] were estimated using the square root of the reciprocal of the mean numbers of vessels per cm^2.

It can be seen that the numbers of capillaries/cm^2, and hence their lengths ($2\times$this[2–4]), are very much less than those found[11] in the human ventricle ($\sim 5\times10^5/cm^2$), in the muscles of various species[11–13] ($1–5\times10^5/cm^2$), or even in the fat of rats[11] ($2–10\times10^4$). While it must be remembered that in the muscles listed[11–13] it is likely that the sections were transverse to the fibres[5] so that the estimated lengths per cm^3 would be nearer to $1\times$the values for capillaries/cm^2, rather than $2\times$this as in random sections[2–4], nevertheless it is evident that the lengths, and the associated capillary surface areas are much less in the present tissues than in the muscles, or indeed in the other regions of the body of a number of species[11]. It is unfortunate that we do not have human skeletal muscle to compare with these findings – since the larger the animal, the less its vascularity[11–13]. Still it is very evident that the tissues we have examined are much less vascularized than muscles and other metabolically active regions. (It should be noted that we have here examined only the deeper layers of the synovial capsule; this is the part most relevant to diving, since air in the superficial layers, which are likely to have more vessels, could easily pass into the joint space).

The intercapillary distance is only approximately estimated by our method[5,6], but a more exact one does not yet seem to be available. It is evident that the distances found here are some 3–10 times greater than those which can be derived from the values for the other sites, quoted earlier. Also the distribution is very wide so that an appreciable proportion of the vessels must be very widely separated indeed. This must have a very great effect on the slow removal of gas from the tissues around the knee, and hence indicates why this region is more prone to develop the bubbles which cause 'the bends' during decompression. It is hoped that the present values, plus those for the capillary surface area, will be used in a model of this disease[9].

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Dog Behaviour as Related to Spinal Cord Temperature

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Summary. 3 dogs could behaviourally modify their own spinal cord temperature ($T_{spin.\ cord}$). In a hot environment, 2 dogs did not cool their spinal cord, 1 dog warmed it. The higher the environmental temperature, the higher the chosen $T_{spin.\ cord}$. These results seem to imply that this latter dog tended, in warm environment, to behaviourally reduce: $T_s > T_{spin.\ cord}$ (T_s mean skin temperature). Data obtained previously support this explanation.

CORBIT[2] has shown that direct thermal intracranial self-stimulation was possible in rats. Rats placed in a warm environment were able to cool their brains by self-stimulation. We considered that it would be interesting to offer the possibility of thermal spinal cord self-stimulation to animals, because: 1. Spinal thermal sensitivity has been shown to be of the same magnitude and efficiency as the hypothalamus in temperature regulation[3,4]. 2. Heating of the spinal cord was shown to be followed by an adequate corrective behavioural response in frogs[5] as well as in dogs[6]. Cooling of the spinal cord was followed by a corrective operant response in pigs[7] and by an adapted posture in pigeons[8].

Methods and results. We used 3 dogs which were previously trained to interrupt a light beam in order to obtain environmental infra-red heat or cool air. Each of the 3 dogs was chronically implanted with a U-shaped spinal thermode made of PE tubing (external diameter: 1.5 mm, internal diameter: 1 mm), through which water was circulated. This thermode was implanted in the epidural space, under general anesthesia, from C_2 down to the caudal end of the vertebral canal. These dogs had been implanted and trained for another experiment, the results of which have been published[6]. The technique consisted in an attempt to transfer the operant behaviour heat or cold reward from the skin to the spinal cord. A

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