

The occurrence and possible functional significance of spiral smooth muscle cells and connective tissue fibers.

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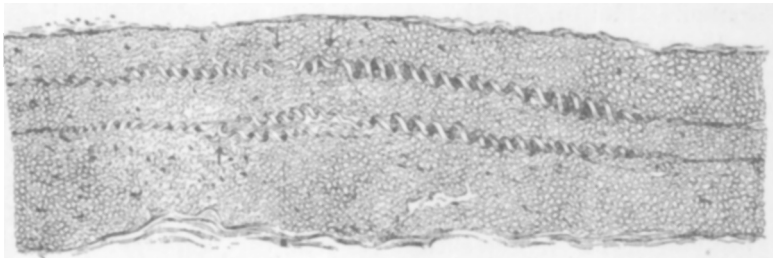
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There is a fairly extensive literature on this subject,¹ which cannot be discussed here even though recent work on the contraction of smooth muscle and the production of tonus pays but scant attention to its possible significance. In this place only those findings will be reported, which, as far as I know, have not been described in smooth muscle and connective tissue.

The material studied was the stomach of the frog, colon of the guinea pig, caecum of the rabbit, and duodenum and lower small intestine of the dog. The chief fixative was Orth's solution. The sections were cut from paraffin blocks.² The most instructive slides were obtained when the plane of the section was tangential to the surface of the gut or parallel to the direction of the spiral fold in the rabbit's caecum.

Results: Muscle nuclei with a spiral or rather helicoid twist

FIGURE 1.



Section through the spiral caecal fold of a contracted rabbit's caecum. The helicoids are stained a bright red with Van Gieson's stain.

At sites marked by arrows a right twist changes to a left one, or vice versa.

¹ For some of the references see Forster, Edm., *Anat. Anz.*, 1904, xxv, 338; Maresch, R., *Centralbl. f. Allg. Path. u. path. Anat.*, 1905, xvi, 641; Fahr, *Virchow's Arch. f. path. Anat.*, 1906, clxxxv, 29; McGill, C., *Am. J. Anat.*, 1909, ix, 493.

² I acknowledge with pleasure that the resources of the Anatomical Department were placed at my disposal by Dr. A. G. Pohlman.

may be observed in every section, particularly if the gut was well contracted. They are most numerous at or near Auerbach's plexus, both in the circular and longitudinal layers. The twist may be a right or a left screwthread, both types occurring in the same field. In numbers of instances the same nucleus showed a right twist in one section and a left twist at the other end. Occasionally the transition site of one twist to the other was beautifully apparent, and on a miniature scale, the same as shown by the accompanying figure 1, observed in white fibrous tissue. The closeness of the twist varied: in the pale vesicular nuclei there was either no twist or 1-2 shallow spiral grooves; with increase in the number of twists the nucleus stained more and more densely, became thinner and often looked like a small closely coiled spring; the densely staining, slender, rod-shaped nuclei showed either a faint twist of steeper pitch than the close spirals or none at all; the pale staining, long, rod-shaped nuclei showed no twist in general. Hemotoxylin and also the pyridin-silver method gave the best nuclear pictures.

The muscle fiber itself also exhibited definite spiral twisting. This spiralling could be either a right or a left twist; in a few instances a left twist was observed on one side of the nucleus while the opposite side of the muscle fiber showed a right twist. In the same field both right and left twists could be observed, though it appeared on counting as if one type usually predominated. Like the nuclei, not all the muscle fibers show a twist; in the same muscle ribbon or sheet, parts show the helicoid twisting which pass by insensible gradations to the non-twisted type. Usually when the muscle fiber showed a twist, a similar one with apparently the same pitch (ocular micrometer) was observable in the nucleus; not infrequently, however, a spiral muscle fiber is seen where the nucleus belonging to it shows no twist and is more or less vesicular. The best pictures were obtained with hematoxylin and eosin, iron hematoxylin, and Van Gieson stains.

The white fibrous tissue as demonstrated by Van Gieson's stain, shows beautiful helicoids, especially when the contracted spiral caecal fold of the rabbit is examined. Figure 1 gives a slightly schematic representation of what may be observed. These white fibrous cords or fiber aggregates run generally more or less at right angles to the course of the smooth muscle fibers in the caecal fold, the muscle fibers themselves being almost parallel to the long axis of this fold. When the plane of the section is

parallel to the long axis of the white fibrous tissue in the spiral caecal fold, these collagen fibers are seen to form helicoids which may have one type of twist throughout their course, or may exhibit one or several nodes of reversal where a right spiral changes to a left or vice versa (see Figure 1 at places indicated by arrows). A similar reversal of twist is seen when a series of old grapevine tendrils is examined.

In tangential sections of the rabbit's caecum showing all the layers, two sets of collagen fiber spirals may be seen running between the muscle fibers, one set parallel to the long axis of the muscle fibers, the other at right angles to this set; this arrangement is particularly noticeable at the base of the spiral fold.

The spiral twisting of the nucleus must express some of the nuclear fluids into the perinuclear spaces of the muscle cell, and the muscle cell subjected to a similar strain must in turn also filter out under this pressure some of its constituents into the fluids bathing the connective tissue fibers. It is readily conceivable that this process may alter the reaction of sarcoplasm as well of the tissue lymph. Thus a spiral contraction of the nucleus could initiate functional changes in the cell body including the sarcolemma of a smooth muscle, and a spiral contraction of smooth muscle similarly might affect the connective tissue elements surrounding it. It should be noted that a spiral twist beginning in the middle of a muscle cell, viz., at the nuclear site, must necessarily produce different twists above and below the nucleus: a right thread above and a left one below or vice versa, depending upon whether the twisting nuclear force was acting clockwise or counterclockwise. This is not the only way in which a reversal of twist may be secured. In a relatively rigid helicoid fixed at one end, rotation of the other end in the same direction as the existing twist will produce nodes of reversal, and a left helicoid can readily be changed into a right helicoid or vice versa. In a subsequent communication this will be described more fully.

Furthermore, it may be observed that these torsions can be utilized to explain certain morphological changes: for example, the change of an ovoid, vesicular pale-staining muscle nucleus into a slender rod-shaped, densely staining structure; or the change from a short thick muscle cell into a long narrow cell. Finally, the effect of torsion upon the length of the nucleus, cell body or connective tissue strand will depend upon the elasticity of the structure involved, which may perhaps be a quality fluc-

tuating with various conditions. If the structure is relatively inelastic, then its shortening must result if twisted into a helicoid; if more or less elastic, a lengthening may occur.

The helicoid twist described cannot be deprived of significance by classing it as an artifact or an abnormal state; if it is due to the reagents employed, the involved structures must have contained compounds different from those found in the non-twisted homologous structures and this means a different functional state. Abnormality on analysis simply means that a normal process has been increased or decreased beyond a certain level, for in no abnormal process is there ever the creation of a new function, there is merely the exaggeration in a positive or negative direction of capacities active or dormant in the cell.

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The time of ovulation in the menstrual cycle of the monkey,
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Available data for placing the time of ovulation in the sexual cycle of primates is meager in comparison to that for other mammals. Much of the evidence consists of the finding of early *corpora lutea* in the ovaries. Since in most cases it has not been possible to correlate the condition of the ovum discharged or its position in the tube with the stage of development of the corresponding *corpus luteum*, this evidence is incomplete.

Recently Corner¹ recovered an ovum from the tube of a monkey on the 14th day of the cycle. This was the first unfertilized tubal ovum of a primate to be recovered after being freed from the ovary. A degenerating ovum was also removed from the uterus on the 17th day of the cycle. In six other animals, all

* This work has been assisted by a grant from the Committee for Research on Sex Problems of the National Research Council.

¹ Corner, George W., *Carnegie Inst. Cont. to Emb.*, 1923, xv, 73.