Papers on Anatomy by M L Kothari et al

Sl.No.	Description	Journal	Co-Contributors
1.	ECTOPIA VESICAE: ITS GENESIS AND SEMANTICS	Journal of Post Graduate Medicine	Meena L Kothari, Jyoti M Kothari and Lopa A Mehta
2.	UROTHELIUM	**-do-**	S M Bhatnagar and K D Desai
3.	FUNCTIONAL SIGNIFICANCE OF TIIE EVOLUTION, AND THE ANATOMY OF THE MAMMALIAN THORACIC DUCT	**-do-**	Lopa Mehta, Jyoti Kothari and Meena L Kothari
4.	VOLUNTARY: MUSCLES OR MOVEMENTS?	**-do-**	S M Bhatnagar and K D Desai
5.	THE SEMANTIC CONFUSION OVER THE ACTIVITY OF SKELETAL MUSCLES IN MAN	**-do-**	-do-
6.	FURTHER OBSERVATIONS ON THE SEMANTIC CONFUSION REGARDING SKELETAL MUSCLES - I	**-do-**	-do-
7.	A NOTE ON A REGION IN THE.FOOT COMPARABLE WITH THE ANATOMIC SNUFF BOX	**-do-**	S. V. Modi
8.	THE NATURE OF BONES AND JOINTS: A NEW PERSPECTIVE	**-do-**	Lopa Mehta and M Natrajan

Reprinted from the "Journal of Postgraduate Medicine", Vol. XVI, No. 1, January 1970, pp. 1-4

ECTOPIA VESICAE: ITS GENESIS AND SEMANTICS

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"As ideas are preserved and communicated by means of words, it necessarily follows that we cannot improve the language of any science without, at the same time, improving the science itself; neither can we, on the other hand, improve a science without improving the language or nomenclature which belongs to it. However certain the facts of any science may be, and however just the ideas we have formed of these facts, we can only communicate false impressions to others while we want words by which these may be properly expressed" (Lavoisier).[12] It is natural, therefore, that "scientific controversies constantly resolve themselves into differences about the meaning of words" (Schuster).[14]

Semantic inertia fogs the clarity of thought and expression with regard to the interesting congenital anomaly erroneously called **ectopia vesicae** or exstrophy of the bladder. The present article aims to elaborate the fallacies inherent in the above terms and to present suitable alternatives based on acceptable logic. The congenital nature of the anomaly makes a brief consideration of its genesis imperative.

GENESIS AND ASSOCIATED ANOMALIES

Ectopia vesicae results from the failure of the mesoderm of the caudal end of the primitive streak to grow into the tailfold. The contact between the ectoderm and the entoderm is temporarily maintained but eventually both these layers break down and disapper in the tailfold region.[6, 11] The failure of all the three layers of the tailfold accounts for bladder extrophy and the gamut of associated anomalies: deficient infra-umbilcal wall, separation of pubis, epispadias, rudimentary and malformed penis, small and cleft scrotum. In the female the clitoris is divided and the labia minora are widely separated.[1, 3, 13] Summarising, one may state that the whole picture of defective development is due to the triple (trigerminal) agenesis of the tailfold.

DRAWBACKS OF CURRENT TERMS

a. The term **ectopia vesicae** is patently wrong. There is no **ectopia** because the trigone is where it would be otherwise. The term **vesicae** cannot be used since there is no fully formed bladder except its posterior wall, the trigone.

From: The Department of Anatomy, Seth G. S. Medical College, Parel, Bombay-12.
Received for publication: 30eth August 1969.

b. Exstrophy means a "congenital eversion or turning inside out of an organ".[4, 5] The bladder, which is itself absent over its lateral, superior and anterior walls, is incapable of executing the process of eversion or turning inside out. There is a certain forward bulging of the surface of the trigone in **ectopia vesicae,** but this cannot be called exstrophy.

It may be concluded that both the current appellations, ectopia and exstrophy applied to the incompletely formed bladder, are erroneous. Both are based on a referential system devoid of clarity.

SUGGESTED TERMS

a. Overt Bladder Trigone:—

This term is based on the mere clinical observation of the exposed, manifest or overt trigone of the bladder. The term is pregnant with a larger meaning. It indicates that

- i. the bladder is where it should be;
- ii. the trigone is naked and bare because—
- iii. the rest of the bladder wall is absent alongwith—
- iv. the absence of the infra-umbilical abdominal wall.

Using the term Overt Bladder Trigone is like referring to the apex of an iceberg, the submerged part of which comprises many other, unstated, anomalies (Fig. 1).

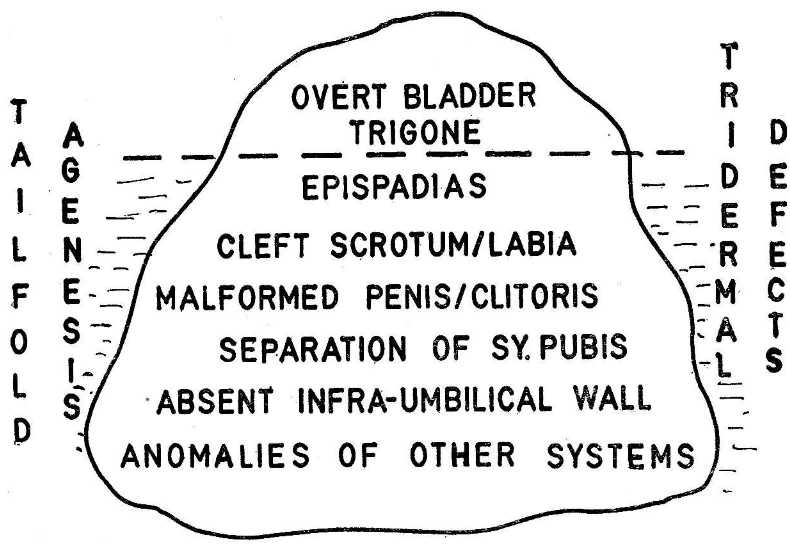

Fig. 1. The iceberg of the anomalies of Tailfold Agenesis.

b. Tailfold Agenesis:—

Failure of the ectoderm, the mesoderm and the entoderm of the tailfold accounts for the host of abnormalities that accompany Overt Bladder Trigone or **ecopia vesicae**. These multiple abnormalities can be developmentally summed up as Tailfold Agenesis, or as Triple Agenesis of the Tailfold.

The above term suffers from an inability to state any of the many morphological abnormalities. This weakness in a way is its asset for it allows all the abnormalities to be summed up in one term. It highlights the trigerminal defects; gives them a common aetiological basis and indicates that there are to be expected many anomalies of the pudendum, the abdominal wall and the urinary bladder.

DISCUSSION

The merit of any descriptive term lies in: having a clear aetiological basis; telling the truth, if possible the whole truth and what is more important nothing but the truth; and in being pregnant with a meaning that is "more than meets the eye". Attempts have been made earlier to evolve terms conforming to these requirements.[7, 8, 9, 10]

It may be submitted that the two terms suggested for substituting the current terms **ectopia vesicae**/exstrophy of bladder meet with most of the above requirements. A fuller meaning can be imparted if the two terms are combined as Overt Bladder Trigone due to Tailfold Agenesis. Though purists in semantology may welcome such an amalgamation, it is not necessary. Overt Bladder Trigone occurs due to Tailfold Agenesis only, and hence, its usage is not likely to signify anything else. Secondly it still satisfies our obscession with the bladder abnormality.

Writing about hypernephroma, Ian Aird[1] comments that of its numerous names, hypernephroma is the most commonly used, nephroma is the most logical, Grawitz tumor is politely noncommital while the term papillary adenocarcinoma is the most accurately descriptive. It would appear that the term Tailfold Agenesis is most logical while the term Overt Bladder Trigone is most truly descriptive of the Tailfold Agenesis.

SUMMARY

It is pleaded that the terms **ectopia vesicae** and exstrophy of the bladder are semantic errors. New terms Overt Bladder Trigone or Tailfold Agenesis have been suggested and their rationale has been explained.

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Reprinted from the "Journal of Postgraduate Medicine", Vol. XIII, No. 2, April 1967.

UROTHELIUM

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The term *transitional epithelium* has come to mean the lining epithelium of the major portion of the urinary tract.[3, 5, 7, 8, 10, 12, 13, 16] The term is inappropriate and without real meaning.[2, 14] In addition to its unfortunate use in describing the specific urinary epithelium, the term *transitional* has been indiscriminately used to describe the lining epithelium of certain areas in the oropharyngeal region[1, 4] and the anal canal.[11]

Basis of the term 'transitional epithelium':

The word *transitional* means changing from one form to another.[6] Transitional epithelium is so named because it appears to change from two or three layers of cells in the distended state of the bladder to five or more layers in the contracted state.[3] This apparent change in the number of layers led to the belief that morphologically the epithelium occupied a position in between the simple and the stratified epithelia[5] and the term *transitional* may have been introduced to denote this midway position.

Some authors[1, 4, 11] have used the term *transitional* to denote the epithelium situated at the junctional zones between two entirely different epithelial types; e.g. in the oropharynx[1, 4] and in the anal canal.[11]

Drawbacks:

Since the term is without a consistent basis, it at once becomes inappropriate and devoid of meaning.[2] Further, its loose usage in the literature, indicating a change in form and type of epithelium at one place and a change in site at another, has created a state of confusion, without, in any way, elucidating the structure or the exclusive function of the specific urinary epithelium.

Urothelium:

Under the circumstances, it is advocated that the term *transitional epithelium* (signifying here the urinary tract lining) be immediately, totally and permanently replaced by a more intelligible term *urothelium.* The merit of the latter lies in the fact that the lining is exclusive[3, 5] and shows distinct structural and functional peculiarities. Also, the term urothelium is akin to the well known term epithelium and endothelium and has been employed by urologists.[13, 17]

Structure of the Urothelium:

The conventional accounts of the structure of the urothelium differ as regards the cell morphology, the cell types, the number of layers and their changeability, and the existence or otherwise of a basement membrane. The

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Received for publication: November 15, 1966.

surface cells are described as bloated, cuboidal and with bulging tops.[2] They may have two nuclei and may be flattened.[5] Their deeper aspect is indented to allow the fitting of the clubbed ends of the middle, larger, piriform cells.[2] The basal cells are small and polyhedral.[2] In a relaxed epithelium, the cells are six or more layers deep.[2, 3] On stretching, the epithelium is thinned out to two or three cell layers, apparently by the cells slipping past each other due to the slimy intercellular substance and the lack of intercellular bridges.[2, 3, 5] The sheet is then more like the stratified squamous non-keratinised epithelium.[2] The epithelium is not indented by papillae and there is no basement membrane.[2]

The electron microscope shows urothelium to be consistently made up of three layers of cells, which do not slide past each other, as was previously assumed, but merely flatten with reduced interdigitation of cell-processes.[15] Reduction in the number of cell layers in a distended bladder is apparent rather than real, being the result of extensive deformation of individual cells.[5] A thin but distinct basement membrane is seen.[12, 15]

Functions of the Urothelium

The structural peculiarities of the urothelium are considered essential for facilitating the rapid changes which occur during the distension and contraction of the urinary bladder.[5, 14] Hay[8] mentions that the arrangement of the cells in urothelium is a truly remarkable adaptation for the special tensions that may develop in the ureters, bladder and the upper part of urethra.

Very little emphasis, however, is laid on the two important and exclusive functions of the urothelium:

(1) It prevents any exchange between the urine and the inter-cellular fluid.
(2) It affords protection against the hypertonic products in the urine.

It will be appreciated that urothelium is to be found in those areas which are constantly in contact with urine. Anastomosis of the ureter to various parts of the intestinal tract results in the reabsorption of many of the urinary constituents.[18] Wetting of the skin in cases of uncontrolled micturition soon makes it sodden and excoriated.[5]

DISCUSSION

The recent trend in anatomic nomenclature is to replace ambiguous terms by those which convey a precise and comprehensive meaning. The term *urothelium* should replace the term *transitional epithelium* because, it carries an implied meaning regarding the specific location, structure and function of the lining. It is confined to the major portion of the urinary tract, shows three layers of cells under the electron microscope and is 'urine proof'.

The notion that the arrangement of cells in urothelium is designed to permit rapid distension and collapse, is an *idee fixe.* The minor and major calyces, the pelvis of the ureter and the ureter are all lined by urothelium, even though they are not subjected to such extensive distension and collapse as the bladder. The stomach and the heart are lined by a simple epithelium, notwithstanding the fact that they are subjected to extensive and sudden distension and collapse.

Urothelium is deceptively similar to stratified squamous non-keratinised epithelium of certain areas. The resemblance is particularly striking in regions like the oro-pharynx[1, 4] and the anal canal.[11] However, the latter usually shows the presence of papillary ridges, keratohyalin, keratin and even melanin.[1] The specific nature of urothelium is indicated by the behaviour of the urothelial tumors. Tumors of the renal pelvis, ureter and the bladder have many similar features. Seventy per cent of renal papillomas are accompanied by ureteric and/or bladder tumors, pari passu or subsequently.[12]

The term *urothelium* can therefore, safely replace the term *transitional epithelium,* without detracting from the traditional significance of the latter.

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Reprinted from "Indian Journal of Medical Sciences"
Vol. 24, No. 7, July, 1970. pp. 414-418.

FUNCTIONAL SIGNIFICANCE OF THE EVOLUTION, AND THE ANATOMY OF THE MAMMALIAN THORACIC DUCT

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"The only way to understand a machine is to understand the purpose the designer had in mind."

Max Kleiber.[12]

The vertebrate lymphatic system consists of a widespread network of thin-walled lymphatics[11,25]. Lymph nodes as well as a well-defined thoracic duct first make their appearance in the birds but reach their consummate development in the mammals[3,11,19,21,25]. The emergence of the thoracic duct in the homoiothermic vertebrates, birds and mammals, elegantly demonstrates a principle that, in the working of the Natural Selection[2], *functional necessity is the mother of structural innovation.* The present communication attempts to illustrate the same with regard to the evolution and the anatomy of the mammalian thoracic duct (Fig. 1).

I. EVOLUTION

Some of the major changes that marked the change-over from poikilothermy to homoiothermy provide the functional basis for the evolution of the thoracic duct.

1. Shift in the adipo-hepatic balance[23]: With the development of well-defined adipose tissue, especially in the mammals, the liver ceased to be an organ of lipid storage[23]. This necessitated a hepatofugal, lymphatic route for the lipids absorbed by the small intestine which, in turn, meant a large quantum of lymphatics and lymph flow from the intestine. Yoffey and Courtice[25] may be quoted, here, to an advantage: "The lymphatic capillaries here have a special function, the absorption of fat, but even in herbivora and especially in ruminants, whose diet is consistently very low in fat, the intestinal lymph flow is high."

One of the important functions of the avian liver is lipid storage[5,21]. Details of lipid absorption in birds are not available; the few studies reported indicate the portal vein as the route of lipid-transport[21]. It is interesting to note that birds do not have as well-defined adipose tissue as mammals[21]. The lymphatic absorption of lipids in mammals has been shown to be Nature's design ensuring lipid homeostasis[13].

2. Marked increase in intra-arterial and intracapillary blood pressure[10,19,25] necessitated an increase in the level and complexity of the plasma proteins,[4,10,14] so as to provide greater osmotic pressure in the plasma to oppose the great increase in filtration presure[4,16,19,25]. Arterial as well as capillary blood pressures show a steady rise from the fish onward, a big jump coming with the change from poikilothermy to homoiothermy[10,19]. The same holds good regarding the complexity and the level of plasma proteins,[4,10,14].

Manufacture by the liver of large quantities of the plasma proteins, especially albumin, needed, for their removal, a rich quantum

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Received for publication, July 16, 1969.

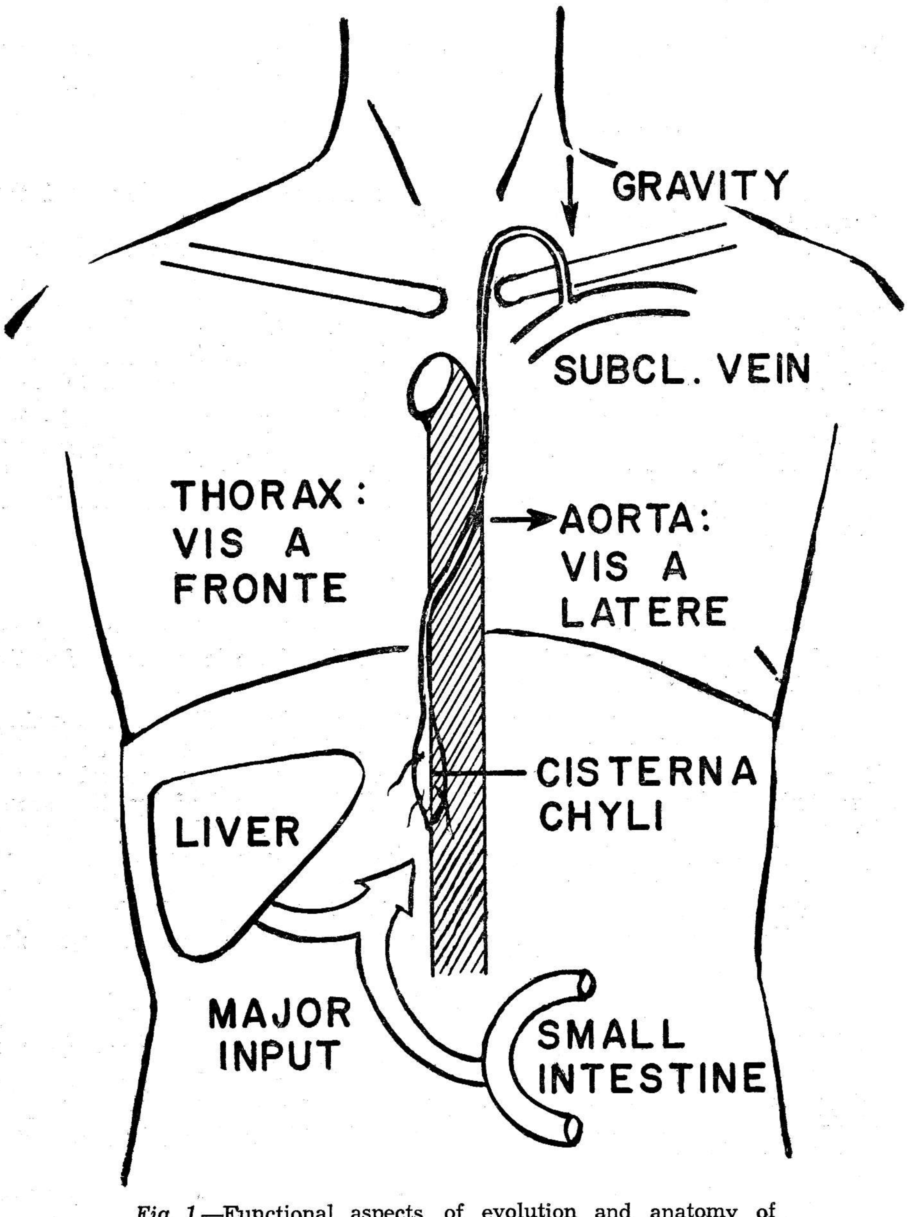

Fig. 1.—Functional aspects of evolution and anatomy of thoracic duct. Presence of numerous, competent valves permits the duct to have the full benefit of *vis a fronte* and *vis a latere*.

of liver lymphatics. In the mammals, the abdominal viscera (especially the small intestine and the liver)[6,25] contribute 80 to 90 per cent of the thoracic duct lymph[6], with 1/3 to 1/2 of the flow[6,16,25] coming from the liver. The intestinal lymph is rich in protein[6,25]. "This relatively large flow of lymph from the liver and alimentary tract in all animals, whether they live on a high or a low fat diet, and whether they are postabsorptive or not, is one of the most striking features of the lymphatic system."[25]

The formation of a reservoir, the cisterna chyli, the sole survivor of a series of lymph sacs formed during embryogenesis[1], took place at the site of termination of the hepato-intestinal lymphatics, near the origins of the coeliac and the superior mesenteric arteries[15,24]. More than 90 per cent of the liver lymphatics[18] and all the intestinal lymphatics[15,24,25] discharge into the cisterna chyli.

It may be summarised here that the evolution of the thoracic duct, in mammals, is largely attributable to the evolutionary changes that affected the liver and the small intestine as a consequence of certain major circulatory and metabolic adaptations.

II. ANATOMY

The duct begins at the upper end of the cisterna chyli, a reservoir necessary because of the intermittent and tardy flow of the thoracic duct lymph[8,16,25]. The appellation *thoracic* is an understatement for the duct is, indeed, an abdomino-thoraco-cervical duct, being only a bird of passage through the thorax. The cisterna and the duct in the abdomen and the thorax maintain an intimate relation with the aorta, deriving from its pulsations the *vis a latere*[7,17,25] for promoting lymph flow. The passage of the duct through the thorax provides it the *vis a fronte*[7,16,25] a suction force applicable to it and the great veins[7]. The duct ascends into the neck, where it executes a U-turn[15,24,25] so as to open into a vein with a lower intraluminal pressure[25], and to direct the lymph flow along the blood stream, assisted, at the same time, by gravity.

From its origin to its termination, the duct is intimately related to the aorta[15,17,25], the left side of the arch, the left common carotid and the left subclavian arteries and it drains the lymph from all the areas supplied by these vessels. Hall *et al*[8] have demonstrated spontaneous contractions in the various lymphatics of unanesthetized sheep, with the pulse pressure ranging from 1 to 25 mm. of Hg. No such spontaneous contractions have been observed in other mammals including man[16]. From the various reports[1,16,25], one would conclude that the thoracic duct flow is largely dependent on the *vis a latere* provided by the arteries and the *vis a fronte* provided by the thorax.

DISCUSSION

Mayerson[16] has termed the lymphatic system as "a relatively inept and inefficient system, rather casual" but nevertheless "a homeostatic mechanism, important in the maintenance of the constancy of the *milieu interieur*". That its complexity has kept pace with the rise of intra-arterial pressure and the rise in the level and the complexity of the plasma proteins, has generally been accepted. The thoracic duct presents the culmination in the development of lymphatic vessels and subserves many important circulatory and metabolic functions. The concept of the evolution of new structures as an anticipatory adaptation (entelechy or aristogenesis)[20,12] does not find acceptance with most biologists[20]. The functional needs which possibly gave rise to the thoracic duct system and the highly suitable way in which it has evolved in the mammals may suggest that Nature does, at times, indulge in entelechy[22], inducing organogenesis by prior thought[22].

Dumont and Rifkind[3] have attempted to provide a functional basis for the evolution of the thoracic duct by only considering part[9] of the dynamics of lymph flow. The present article may afford a larger understanding of not only the evolution but also the anatomy of the mammalian cisterna chyli and the thoracic duct: their beginning in the upper abdomen, the passage through the thorax and the the termination at the root of the neck.

SUMMARY

An integrative concept has been presented to provide a functional basis for the evolution of the mammalian thoracic duct.

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Reprinted from the "Journal of Postgraduate Medicine",
Vol. XIII, No. 4, October 1967

VOLUNTARY: MUSCLES OR MOVEMENTS?

Concluding Observations on the Semantic Confusion Regarding Muscles

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"As ideas are preserved and communicated by means of words, it necessarily follows that we cannot improve the language of any science without, at the same time, improving the science itself; neither can we, on the other hand, improve a science without improving the language or nomenclature which belongs to it. However certain the facts of any science may be, and however just the ideas we have formed of these facts, we can only communicate false impressions to others while we want words by which these may be properly expressed"[10] (Lavoisier). It is natural, therefore, that "scientific controversies constantly resolve themselves into differences about the meaning of words"[15] (Schuster).

Semantic inertia persists in the use of a large number of terms in Anatomy and Physiology. The terms *voluntary* and *involuntary* as applied to muscle types are notable examples of the same inertia. The earlier articles[8, 9] have endeavoured to discuss a few terms concerning muscle action. The present communication attempts to shift the emphasis of the terms *voluntary* and *involuntary* from muscles to movements; i.e. from the periphery to the centre. Such a shift in emphasis is desirable because of the narrow and often erroneous impression conveyed by the use of these terms in describing muscle types.

The brain and the spinal cord with nerves and muscles constitute an indivisible system. Muscles from a functional point of view, are only a part of the brain.[3] It is movements......and not individual muscles which are represented in the cerebral cortex[5]. When a movement is carried out, a definite combination of muscles is called into play and no muscle can be omitted nor can one be added voluntarily[5]. The terms *voluntary* and *involuntary* are more appropriately applicable to the types of the activity of the central nervous system than to the muscle types, particularly because one is only aware of a resultant movement, and not of muscles concerned with it.[18]

The Current Classification:

Muscle tissue is classified into three varieties.[1, 4, 5, 7, 11, 12, 13]

A. Voluntary, striated, skeletal or somatic.
B. Involuntary, non-striated, smooth, plain or visceral.
C. Cardiac or heart.

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Received for publication: August 22, 1967.

The first variety, supplied by the cerebrospinal nerves, and completely *dependent* for its activity on these nerves, is called *voluntary* since almost invariably, at least in man, it can be brought under the control of the conscious will, being under the dominance of the highest functional levels of the central nervous system in the cerebral cortex.[1, 7, 11] Skeletal muscles are under the control of the will; hence, they are alternatively called voluntary muscles.[4]

The other two varieties contract *independently of voluntary control* and therefore, are *involuntary*[1]. Cardiac musculature shares the characteristic of transverse striations with voluntary musculature, inspite of its automatic, rhythmic and involuntary function. The heart and the visceral musculature retain their ability to function even in the absence of nervous control.[11]

It is clear from the foregoing that the terms *voluntary* and *involuntary* as applied to muscle tissue are inapt.

The Suggested Classification:

Since muscle tissue functions merely as an agent of the nervous system in bringing about or checking any movement, its classification should be based on its behaviour in response to the controlling authority of the nervous system.

CLASSIFICATION

1. Structural basis:

- Striated
  - Multinucleated fibres
    - Somatic
    - Visceral
  - Mononucleated fibres
    - Cardiac
- Smooth or plain
  - Somatic
  - Visceral

2. Topical basis:

- Somatic
  - Striated
  - Plain
- Visceral
  - Striated
  - Plain
- Cardiac
  - Striated

3. Functional or Motivational basis:

- Automotive or Independent
  - Smooth or plain
  - Cardiac
- Non-automotive or Dependent
  - Voluntary, somatic skeletal or striated

It is well known that the development of cross striation in muscle tissue is an adaptation for the speed of contraction or relaxation, and that its non-development makes for a slow and sustained activity. Therefore, both the smooth and the striated varieties of muscle are encountered to a variable extent in the somatic and visceral portions of the body. The cardiac muscle occupies a unique position in retaining its automatic, rhythmic contractility and yet acquiring the faculty of rapid contraction by developing cross-striation. It would appear that, voluntary or skeletal muscle, while becoming highly specialised for speed, has had to pay a price by losing its automaticity and becoming thereby completely subservient to the cerebro-spinal nervous system.

The Gamut of Muscular Activity:

The activities of the digestive and respiratory systems as exemplified by the involuntary actions of the striated musculature of the soft palate, the pharynx and the upper oesophagus in deglutition; the external anal sphincter in defecation; and the larynx, the diaphragm and the intercostal muscles in respiration, point to the prime importance of precision and speed of contraction rather than of volition.

The inevitable, automatic and reflex association of the striated thoraco-abdominal musculature in expulsive efforts such as sneezing, coughing, micturition, defecation and parturition, illustrates the extensive, involuntary role played by the so-called voluntary muscles.

The limited volitional control over the smooth musculature is illustrated by the mechanism of accommodation of the eye; the voluntary initiation of micturition; and the voluntary inhibition of defecation.

The human upright posture is maintained and adjusted by the alternate, reflex and automatic contraction and relaxation of the opposing muscle groups in front, at the back and the sides of the entire body[17]. This, in fact, produces a constant involuntary swaying—"movement upon a stationary base"[6]. A voluntary prevention of this sway produces a tendency to faint for want of adequate venous return to the heart[17]. In this instance, the activity of the entire skeletal musculature of the body is as rhythmic, automatic and involuntary as that of the intestine or the heart.

It is, indeed, remarkable that an activity as ordinary as the human walk is as distinctive and individual as the voice, the face, the finger-prints or the handwriting of a person[16]. Walking is essentially a series of habitually co-ordinated, reflex, automatic and almost unconscious movements and has a backdrop of predeterminism governed by the genetic as well as the environmental factors. It is robbed of its ease, efficiency and grace by any volitional restraint exercised over any of its component movements[17]. Somnambulism illustrates the automatic and unconscious nature of the activity of walking. That an individual can often be identified merely by the sound of his footsteps indicates its distinctive character.

In the instances cited above and in all forms of motor learning and skilled movements, where the so-called voluntary musculature functions automatically, reflexly and involuntarily to achieve the definite aim of a coordinated pattern of movements, it is absurd to describe muscle groups, aiding by their relaxation, the smooth performance of a movement, as *antagonists*. It is equally absurd to describe the helpless attitude assumed by a joint or a limb after paralysis of a muscle group as being due to the *unopposed action* of the *normal muscles* which, in fact, are paralysed, as it were, in a state of shortening, being unable to relax and alter the position of the joint or the limb.

DISCUSSION

The precise basis of volitional movement is not clearly understood; nor are the innumerable, intricate and yet beautifully coordinated neuronal pathways involved in any motor activity, however trifling. Under such limitations, the use of ambiguous designations such as *voluntary* and *involuntary* to describe the various muscle types tends to create a lop-sided perspective. The entire neuromuscular apparatus—visceral, cardiac and skeletal—appears to be end-oriented. It is the total sensory input, and the imprints of evolution, heredity, motor learning and the spontaneous will, which collectively govern the behaviour of the whole neuromuscular apparatus. It is only the resultant, overt movement which can be characterised as voluntary or involuntary and not the muscles concerned therein. It is, therefore, desirable to shift the emphasis from the periphery to the centre and use rational bases for classifying muscle tissue.

The attempts in the earlier[8, 9] and the present, concluding communications may smack of semantic iconoclasm. However, "an error is never so difficult to be destroyed as when it has its root in language" (Bentham)[2]. It was, therefore, thought advisable to try to clarify some of the prevalent ambiguity regarding muscles and their function, and to replace erroneous terms by appropriate ones.

SUMMARY

A rational classification of muscle tissue based on microstructure, location and function has been presented. Muscle has been classified as striated and smooth or plain; somatic, visceral and cardiac; automotive or independent and non-automotive or dependent. The terms automotive and non-automotive shift the emphasis from the periphery (the muscles) to the central controlling mechanism of the nervous system and also take into account the degree of dependence of the muscle tissue on the nervous system.

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Reprinted from the "Journal of Postgraduate Medicine,"
Vol. x, No. 2, April 1964

THE SEMANTIC CONFUSION OVER THE ACTIVITY OF SKELETAL MUSCLES IN MAN

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A volitional movement, crude as in picking up an object or jumping up and down, or elegant as in executing a Bharat Natyam pose or a late-cut in cricket, involves a beautifully co-ordinated mechanism wherein many muscles partake[6, 11]. This co-ordination is ensured by the manifold connexions which exist within the central nervous system[4, 6].

It is movements, however, and not individual muscles which are represented in the cerebral cortex[4, 7, 11, 13]. While performing a movement, one is not conscious of the events occurring in the nervous system or of the muscles producing the movement[13]. One wills to "bend the arm" and it happens[13]. A definite combination of muscles is called into play and no muscle can be voluntarily omitted nor can one be added[4].

The muscle-wise analysis of any movement is an artificiality necessary for academic purposes[11]. A particular muscle can play various roles (vide discussion later on role, action and function) as a prime mover, antagonist etc. Various terms have been employed to designate the different roles. Unfortunately, these terms have been given varying connotations in different fields[11]. It is felt that some of the terms, besides betraying a wrong connotation, fail to convey any positive information about the importance of the role played by a muscle. An attempt is made in this paper to clarify the confusion that exists in the use of various terms in relation to the different aspects of skeletal muscle activity in man.

Terms employed by various authors:

John Hunter, in 1777, described the actions of the muscles as being immediate and secondary, the former being concerned with the direct production of the movement required and the latter with the supporting actions accessory to the main action[6]. This classification, obviously, is too simple. Later, too many terms have been used: **agonist**[1,11,] **protagonist**[8, 13]; **prime movers**[3, 4, 5, 6, 7, 9, 11]; **movers**[10, 12]; **emergency muscles**[5, 11, 12]; **neutralisers**[10, 12]. The terms **antagonists, fixators** and **synergists** have been used by all, Wells[11] having dropped the term synergists.

Agonists, Protagonists:

These have been derived from **agon — struggle**, probably from the fancied imagination that the prime movers are **struggling** to contract against the

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Received for publication: March 9, 1964.

resistance offered by the antagonists. An agonist has been defined as a contracting muscle engaged in the movement of a part and opposed by an antagonistic muscle[1]. The protagonist may be dubbed as the **struggling-muscle-in chief.** There is never any conscious or unconscious struggle involved on the part of the prime movers and thus all the terms (vide next) derived from **agon** should be summarily dropped.

Antagonists:

Repeated usage has carried this misleading term from book to book, but its usage is most unfortunate[7] and belies the function of muscles in that capacity for they do everything to secure harmony in a movement[3]. It is submitted that the so-called antagonists only serve as true antagonists in certain central nervous system lesions characterised by various types of spasticity. In a normal movement, an antagonist responds to a stretch by active relaxation[7]. In spastic disorders, the exaggerated stretch-reflex makes them respond to a stretch by contraction[7, 13]. An antagonist has also been defined as a muscle that acts in opposition to another[1]. That this is wholly untrue, in health, cannot be over-emphasized.

Some authors have tried to escape from this semantic error by defining an antagonist as one which produces a movement reverse to that produced by the prime mover[3, 6, 11, 12]. Such a definition fails to assign any role to the antagonist during the primary movement and takes no care of the fact that when it does produce the reverse movement, it becomes a prime mover on its own.

It is not always that the antagonist does just the opposite of the prime mover. Both can contract simultaneously, just as biceps brachii and triceps do to steady the elbow[2, 6, 7, 10]. It is this fact, viz. the ability of the prime movers and the antagonists to contract at the same time that has led some to doubt the validity of Sherrington's phenomenon of reciprocal innervation and inhibition operating under normal conditions[11].

Prime movers, Movers, Emergency Muscles:

Both the terms — prime movers and movers — convey the role played by the muscles which, by their active (concentric[7], [11]) contraction and approximation of their attachments bring about the actual movement at a joint[3]. Wells has probably dropped the term 'prime' since there are often several prime movers producing a movement. We support this omission. She conveniently subclassifies the movers into principal and assistant movers. The emergency muscles[5, 11, 12] which come into play when an exceptional amount of force is needed are a form of assistant movers only and hence this usage has not found favour with other authors.

Synergists, Fixators, Neutralisers:

The meaning of the word synergist has become generalised[11] and it is hopeless to try to enforce the exact usage[9]. Synergists have been called as special form of fixators[3, 7, 11] whereas others do not see any essential difference between synergists and the fixators[4, 6, 8]. We are in agreement with Wells[12] that the term 'synergists' can be dropped from usage. The term 'neutralisers' has been used to mean those muscles which contract to counteract an undesired action of another contracting muscle[11] or of one of the movers[12]. It is apparent that the role of neutralisers is to fix or steady the joint during movement in a particular desired plane and hence the term can be omitted and the socalled neutralising action be assigned to the fixators. When the external obliqus abdominis muscle contracts on both sides simultaneously, the lateral pulls and rotational tendencies are neutralised, giving pure flexion of the spinal column[11]. It is submitted here that each external oblique, besides acting as a mover, fixes the pull of the other in the desired plane. Hence a mover can have a fixator component (Analogous example is flexion of wrist caused by flexor carpi ulnaris et radialis).

Ligament-like role:

It is urged that this important role of skeletal muscles in stabilizing a joint needs to be emphasized. The short muscles round the shoulder and the hip joints serve as **'ligament actifs'**[9] or as **'extensible ligaments'**[6]. It needs to be realised that all muscles round a joint, long or short, are concerned, to a lesser or greater extent, with the important function of acting as stretchable or extensible ligaments. The stability of the wrist depends on the long muscles on all its sides. With paralysis of the deltoid, the humeral head can be subluxated by pulling the arm away from the shoulder. The quadriceps femoris is important in preventing forward dislocation of femur over tibia when the flexed knee is bearing the weight of the body. Ligaments should be looked upon as messengers which when stretched convey to the muscles the message to contract, a reflex mediated by the Hilton's law of joint innervation. The ligaments stretch rapidly when muscular safeguard is removed or diminished[3]. It may be argued that the word **stabiliser** can be used to signify the ligament-like role of muscles. Such usage, however, is bound to lead to ambiguity since the words fixators and stabilisers have been used synonymously[11, 12]. We feel that the word **ligament-like** conveys the proper role played by the muscles.

The role of two-joint muscles, hamstrings being the classical example, has been discussed in detail[2, 7, 11, 12]. Lockhart[7] mentions that ligamentous action of muscle occurs when they are unable to lengthen sufficiently to allow full movement of a joint. The two-joint muscles can be looked upon as extensible ligaments extending over two joints and capable of limiting thus the movements of both the joints when the algebraic sum of the stretch to which they are subjected at the two joints exceeds their stretchability or extensibility. Majority of the two-joint muscles are not so tight as the hamstrings[11]. The extra-tightness of the hamstrings is attributable to the fact that each of the three hamstrings is tendinous or membranous over one-third to one-half its length, so that the length of muscle fibres in each becomes comparable to that of one-joint muscles.

The Concept of Graduators:

Since the usage of the term 'antagonists' is unfortunate[7] and wholly unsatisfactory (vide supra), it is suggested that it be replaced by the word **graduators**. This term, as will be seen later, conveys the all important role played by the so-called antagonists.

The **graduators** in any movement of a joint are those muscles (or a muscle) which are anatomically situated opposite the movers and are concerned with graduating or harmonising the action of the latter. It will be clear that the graduators and the movers at any joint, can interchange their roles.

The importance of the role played by the so-called antagonists has been described adequately[3, 6, 7, 8]. As the prime mover contracts, its antagonist actively relaxes in a **graduated** (emphasis authors') manner to a corresponding degree, 'paying out the slack' so as to render the movement smooth and even, both coming into activity at the same time[6]. The antagonist gives out as fast and as much as, and no more than, the prime mover needs, thus affording guidance and precision to the latter[3]. The behaviour of the antagonists is not passive but is delicately balanced to regulate the movement by exciting the exact amount of restraint necessary[8]. The antagonist assists, relaxing as the prime mover contracts. The relaxation is just as important as the prime mover's contraction[7].

From all that has been said above, it is urged that the term **antagonists** should be replaced by the meaningful term **graduators.** When the graduators are paralysed, the (prime) movers are unrestrained and this leads to deformity at the joint in the direction of contraction of the movers, thus throwing even the latter out of action. Rasch and Burke[11] in their analysis of the kinds of muscular team work rightly emphasize that the more delicate the movement, the greater is the role played by the **graduators.**

Gravity-movements[8] and Graduators:

Gravity-movements are those where the force due to gravity acts as the mover, e.g. flexion at the hip and the knee as in squatting down from standing position. These movements are strictly controlled (and thus executed smoothly) by the graduators. That the activity of the graduators is consciously directed is evident from the following example — when a subject is dropping himself onto a chair from standing position, and someone takes the chair away without his noticing it, the subject tumbles down. This happened since he had actively relaxed (or decontracted[7]) his graduators (gluteus maximus and quadriceps femoris) only upto a point when his gluteal region would reach the chair. It is thought sometimes that gluteus maximus paradoxically flexes the hip. It would be better to state that it graduates flexion at the hip joint when force of gravity is the mover.

Suggested Classification of the roles played by skeletal muscles:

The authors suggest that the following terms be used in assigning different roles to different muscles in a movement at a joint: Movers (principal and assistant)[12], graduators, fixators and ligament-like.

The concept of Restorers:

From Table 1, it will be realised that there is a gross disparity in the bulk and the work capacity between the opposite groups of muscles at the ankle, toes and the fingers. To take ankle as an example: Dorsiflexion at the ankle from the resting position is very uncommonly needed for doing any purposeful action. The dorsiflexors, therefore, are concerned only with one important action and that is restoring the neutral position after the powerful plantar flexors have completed their action. Once the neutral position is restored, the plantar flexors are put to a sufficient stretch and are ready to contract again. The same applies to the dorsiflexors of the toes and to a lesser extent, to the long extensors of the fingers.

TABLE 1

	Cross section in square cms.	Maximal work capacity in kg. m.
Dorsiflexors of ankle	13.2	4.27
Plantarflexors of ankle	64.2	18.68
Long toe extensors	3.4	0.88
Long toe flexors	7.3	2.52
Ext. dig. comm.	4.30	1.720
Long digital flexors (sublimis et profundus)	21.5	9.351

(From Brunnstrom[2] after Fick)

Some generalisations will not be out of place regarding the **restorers.** These are muscles significantly weak in strength and bulk; have little primary purposeful action to offer; the range of movement from the resting position is much less than the opposite movement; when the joint is unsupported or immobile for long, contractures develop in direction opposite to that of restorers. That is why foot drop occurs in patients bedridden for long and fingers go into contracture usually in flexion. Various grips assumed by the human hand[11] involve flexion at all the joints of the fingers. Primary extension at the metacarpo-phalangeal joint, where the extensor digitorum communis acts is only occasionally needed, as while playing carrom.

Role, Action and Function:

Teachers and authors use these terms with regard to various forms of skeletal muscle activity with a certain amount of arbitrariness and hence with a certain amount of looseness. It is felt that these terms need to be clearly defined.

Role is the part or character one assumes[10]. Since it is in acting as a mover, graduator etc. that a muscle assumes various characters, the word **role** should be used when discussing these aspects of muscle activity.

The word action is applied properly to those exertions which are consequent on volition[10]. Since it is assumed that we 'contract' brachialis to flex the elbow (that is why it has been called the prime flexor), it is reasonable to say that the **action** of brachialis is to flex the elbow. In other words, a muscle in the role of a mover, executes its **action.**

Function is the mode of action by which an organ fulfills its existence[10]. Hence this word can be applied to the various duties[10] served by the skeletal muscles. Thus the **functions** of skeletal muscle are:—

(1) bring about or assist movement at a joint,

(2) serve as restorers at the joints of the hand and foot,

(3) serve as a diaphragm between body cavities or cavity and the exterior,

(4) serve as sphincters (e.g. sphincter ani externus),

(5) regulate carbohydrate metabolism[13].

(6) participate in endogenous production of heat[13].

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Reprinted from the "Journal of Postgraduate Medicine",
Vol. XII, No. 3, July 1966.

9

FURTHER OBSERVATIONS ON THE SEMANTIC CONFUSION REGARDING SKELETAL MUSCLES—I

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In an earlier article[5] a plea to rationalise the nomenclature of the roles of skeletal muscles was made, and the terms *movers* (principal and assistant), *graduators* (the so-called antagonists), *fixators* and *ligament-like* were imparted a precise meaning and recommended for general use. In the present communication, the terms *origin* and *insertion* of a muscle have been taken up for deliberation and the concept of *graduators* and *restorers* is discussed further.

The Basis of the Terms ORIGIN and INSERTION

Two concepts appear to have guided the various authors in the use of these terms:

1. That of the relative fixity of one attachment and of the relative mobility of the other in the usual actions of a muscle.
2. That of proximo-distal orientation of muscles, especially in the limbs or their proximity or otherwise to the median plane in the trunk.

That the above bases are loose, ambiguous and often misleading is evident from the extracts from the various authors, who, however, have continued to use the terms *origin* and *insertion* in spite of the obvious drawbacks. All the authors[1, 2, 4, 6, 7] have been unanimous in condemning the terms *origin* and *insertion* and yet none has advocated a replacement of these by more appropriate terms.

"But the terms are unfortunate and the word 'attachment' should serve in each instance as the fixed points are reversed in certain actions."[2]

"The contraction of a muscle results in the approximation of its insertion to its origin but the terms are arbitrary and used for convenience only, and it frequently happens that the contraction of a muscle may result in the approximation of its origin to its insertion."[4]

"In many muscles, it is hardly possible to state which are normally the fixed and movable attachments, and in these cases the application of the terms *origin* and *insertion* is mainly a matter of convention."[1]

"Indeed, in the muscles running from the leg to the foot, the so-called insertions are usually the fixed points. It is sufficient to know origin and

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Received for publication: May 20, 1966.

insertion as attachments so that the most important feature of any muscle, namely its action, may be roughly, though not always accurately, judged by approximating the two attachments."[6]

"Under certain circumstances, almost any muscle may reverse its effective points of origin and insertion. . . . The descriptive points of origin and insertion, however, are determined with reference to the usual actions of the muscles and the terms are not changed in conformity with changed actions."[7]

Drawbacks:

A skeletal muscle must be regarded essentially as the inter-position of a contractile element between two or more skeletal* sites of attachment. On the contraction of the muscle, each site of attachment is capable of being approximated to the other separately or simultaneously. Thus, if A and B are two points of attachment (Diag. 1) of a Muscle M, the length of AB may be shortened by

(i) movement of B towards A
(ii) movement of A towards B
or (iii) movements of both A & B towards each other.

Diagram 1: Muscle M with its attachments A and B.

The terms *origin* and *insertion* not only fail to convey this dynamic concept of muscle action, but also appear to suggest a parallel with the origin,

*Skeletal here means not only bone and cartilage, but also any other connective tissue frame-work of attachment e.g. the sclera, tendon, raphe, fascia, ligament, etc.

course and termination of nerves and arteries. Muscle does not "originate" and run or flow from one place to another, like a nerve impulse or blood stream, and get "inserted" or terminated at another point. A student, therefore, needs to be actively weaned away from the idea that a muscle has an *origin* being its fixed and static point and an *insertion* being its mobile and dynamic point. This basis of relative fixity and mobility is, therefore, unreal except in the instances like the extrinsic muscles of the eyeball and certain facial muscles. A consideratioin of the actions of the lower limb muscles exposes the fallacy of the above basis beyond doubt. The essential function of the lower limb is weight-bearing and locomotion for which it must be regarded as a stable pillar on which the trunk moves, necessitating the relative fixity of the so-called insertion of the lower limb muscles.

Proximal-Distal attachments:

These convey no meaning as in the case of trunk, head and neck musculature, e.g., rectus abdominis, erector spinae, occipito-frontalis, the diaphragm, etc., where it is obviously difficult to decide which attachment is proximal and which is distal.

In the limbs, the transversely placed muscles cannot be said to have proximal and distal attachments, e.g. quadratus femoris, pronator quadratus etc. In the lower limb in particular, the distal attachment usually functions as the origin, as mentioned earlier.

It is clear from the above that the terms 'origin' and 'insertion' as also the twin bases of these viz. 'fixity-mobility' and 'proximo-distality' are not applicable universally, are misleading and therefore, need to be discarded forthwith. "We may think that we have firm hold on a name and know exactly what it means, only to find out that while our back was turned the meaning had shifted. But perhaps this is one of the charming features of life."[3]

Suggested scheme for Muscle Attachments

A well defined and universally accepted set of descriptive terms exists in Anatomy, viz. anterior — posterior, lateral — medial — median; superior — inferior; superficial — deep; central — peripheral; palmer/planter — dorsal. It is logical to use these terms in various combinations to describe the attachments of a muscle. Their usage not only bypasses the ambiguity of the earlier criteria but also has the added advantage of clearly indicating the lie of a muscle and the effective direction of the muscle fibres, from which the probable actions of a muscle could be easily inferred. This scheme also imparts the freedom to accord priority of description to any of the attachments of a muscle, the choice depending upon the customary or the usual action of a muscle or upon the need for emphasising any particular action of a muscle. Thus the vertically disposed muscles, have (i) a superior and an inferior attachment e.g. intercostals, interossei and lumbricals of hand, biceps brachii, triceps, brachialis; (ii) an inferior and a superior attachment, e.g. gluteus maximus, gluteus medius and minimus, adductor longus, hamstrings gastrocnemius, soleus, popliteus or (iii) attachments, any of which may be described first e.g. sternomastoid, rectus abdominis, psoas major, quadratus lumborum. Similar groups can be made of muscles disposed antero-posteriorly (sagitally) or from side to side (coronally). Occipitofrontalis has posterior and anterior attachments for each of its occipital and frontal bellies. The digastric has an anterior, a posterior and an inferior attachment. The trapezius and latissimus dorsi have medial and lateral attachments. The diaphragms have peripheral and central attachments. The examples cited above substantiate the universal validity of the suggested scheme.

Graduators:

The term *graduator* was introduced in the earlier article[5] as a substitute for the term *antagonist* to indicate the positive role played by a muscle or muscle group.

A *graduator* functions as an active controller of the extent and speed of a movement, not unlike the counterpoise in a lift (elevator) (Diag. 2) or a winch.

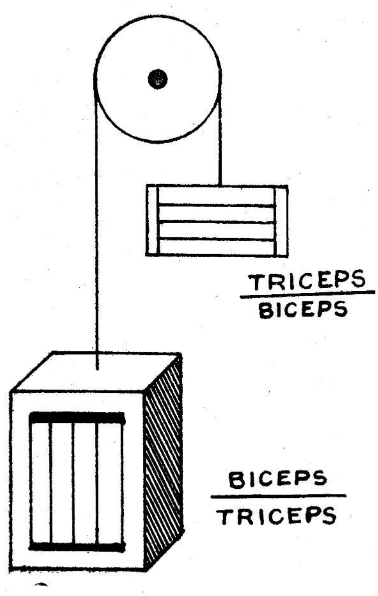

Diagram 2: A **graduator** functions just like the counterpoise in an elevator; e.g. biceps brachii or triceps can each play this role in the movements at the joint.

The various roles played by *graduators* would be evident from the following:

1. In a movement which is rapidly executed the graduators relax at once with the contraction of the *movers.*

2. In a movement carried out against resistance, *graduators* are relaxed since the resistance itself serves to graduate the *movers.*

3. In a slow, precise and controlled movement the *graduators* pay out just as much rope and as gradually as the *movers* need. Without such active assistance from the *graduators,* no skillful movement would be possible.

4. In a movement carried out by the force of gravity, e.g. the flexion of the hips and the knees in attempting to sit from a standing position, the graduators (extensors of the hips, and extensors of the knees) actively regulate the movement which would have ordinarily been produced by the contraction of the movers, namely, flexors of the hip and the knee. In an anti-gravity movement, e.g., rising from a sitting position, the same extensors are required to actively contract as movers, the force of gravity acting as the *graduator.* The rapid fatigue of the gluteus maximus and especially the quadriceps femoris after sit-ups drill is an example in point.

In paralysis of various muscle groups, say, in the limbs, the abnormal attitudes of the joints should be regarded as a result not of the unopposed active contraction of the normal movers but of the helpless contraction of these movers which, in a sense, are functioning abnormally in the absence of the graduating influence. The normal *movers* are, thus, rendered out of function.

Restorers

The general characteristics of *restorers* were outlined in the earlier communication.[5] The long extensors of the fingers and toes, the dorsiflexors of the ankle, the flexors of the knee, the extensors of the wrist, the strap muscles of the neck, and in a special sense, the spinal extensors and the levator palpebrae superioris are examples of restorers.

These relatively weak muscles do not perform a primary purposeful movement. Such a movement is carried out in daily life-skills by a vigorous and often powerful concentric contraction of a set of muscles which activate the joints to some purpose. The opposite movement of the joint is brought about by the weak *restorers* merely to enable the contracted powerful *movers* to regain their initial length and get ready for further useful contraction. Thus *restorers* would appear to merely reactivate the *movers* rather than to carry out any purposeful movement by themselves. The *restorers* may be compared with the pickers on the tennis court. While the players are actively engaged in the game, the pickers are only concerned with bringing the ball back into the game to keep it going.

SUMMARY

A plea has been made to rationalise the description of skeletal muscle attachments. It has been suggested that the terms *origin* and *insertion* be discarded and standard anatomic descriptive terms be used to indicate the attachments of a muscle. The terms *graduators* and *restorers* have been further elaborated.

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Reprinted from the "Journal of Postgraduate Medicine,"
Vol. VIII, No. 2, April 1962

A NOTE ON A REGION IN THE FOOT COMPARABLE WITH THE ANATOMIC SNUFF BOX

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McGregor[1] has laid down the similarity of the plans of the construction of the human hand and foot. We would like to add an additional note. Corresponding to the so-called "Anatomic snuff box" in the hand, there is a similar space in the human foot. The features of each have laid down in the following table for comparison.

TABLE

Features	Space in the human hand (Anatomic snuff box)	Space in the foot
1. Situation	Lateral aspect of the wrist, i.e. along the PRE-AXIAL BORDER of the upper limb.	(Antero-) medial aspect of the ankle, i.e. along the PRE-AXIAL BORDER of the lower limb.
2. Shape	Inverted pyramid.	Inverted pyramid.
3. Shown by	Abduction of the hand with extension of the thumb.	Adduction—inversion of the foot, with extension of the great toe.
4. Occasioned by	Relatively greater prominence of the styloid process of radius with respect to the lateral part of proximal carpus.	Relatively greater prominence of the malleolus of the tibia with respect to the medial part of the proximal tarsus.
5. Roof	Traversed by the cephalic vein. (Pre-axial vein).	Traversed by the long saphenous vein. (Pre-axial vein).
6. Skin of the roof	Fixed to the deep fascia.	Fixed to the deep fascia.
7. Floor*	Formed by— (a) Lateral surface of lower end of radial styloid. (b) Lateral surface of carpal navicular.	Formed by— (a) Medial surface of lower end of medial malleolus. (b) Medial surface of (anterior part of) talus which corresponds to the carpal navicular (McGregor).
8. Bound by	Tendons on either side Extensor poll longus and abductor poll breves et abductor poll longus.	Tendons on either side Tibialis anterior and Extensor halucis longus et Tibialis posterior

* An additional part of the floor is formed by the trapezium (multiangulum majus) in the hand and by the tarsal navicular in the foot. They are however not similar embryologically.

This description further strengthens the plan of structural and functional similarity of the human hand and foot.

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Received for publication: February 23, 1962.

JPGM
Journal of Postgraduate Medicine

Open access journal indexed with Index Medicus & EMBASE

ORIGINAL ARTICLE

Year : 1990 | **Volume** : 36 | **Issue** : 3 | **Page** : 143-6

The nature of bones and joints: a new perspective.

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Abstract

In human ontogeny recapitulating phylogeny, bones arrive late on the scene--long after neurogenesis, musculogenesis, organogenesis and so on are over--as islands of ossification in an ocean of collagen. This study confirms this developmental sequence by demonstrating, in cadavers, the rather independent nature of bone, to which nothing--muscle, tendon, ligament or articular cartilage--is attached. Bone is like the air in a tubeless tyre; it gives rigidity and shape to the tyre, and in return takes the shape of the tyre. The tibia, for example, is the bony tissue that is contained in tyre-like casing made of peritibial soft tissues whose inner limit is the periosteum, which continues proximally and distally as capsules of knee/ankle joint, and to which only are the articular cartilages of the knee and ankle attached, being clearly free from the bones. This study also exposes the truer nature of a joint wherein the articular cartilage assumes anatomic and physiologic significance hitherto unthought of.

How to cite this article:
Kothari M L, Mehta L A, Natrajan M. The nature of bones and joints: a new perspective. J Postgrad Med 1990;36:143-6

How to cite this URL:
Kothari M L, Mehta L A, Natrajan M. The nature of bones and joints: a new perspective. J Postgrad Med [serial online] 1990 [cited 2014 Nov 26];36:143-6
Available from: http://www.jpgmonline.com/text.asp?1990/36/3/143/844

Full Text

:: Introduction

Modern physics has it that all the visible stars and planets, galaxies and nebulae constitute a mere 10% of the material universe comprising 10 84 atoms. The remaining 90% is in the form of invisible plasma forming the invisible matrix from which stars are made and into which stars dissipate.

The bones of the human body are comparable to the visible part of the universe; they seem to be the core round which the trunk and limbs are constructed. Muscles, tendons and ligaments are "attached" to them; the brain and the cord are housed or "contained" in the skull and the vertebral canal. Nerves pass through a foramen or a bone.

In reality, the bones - the skeletal system - are nowhere in early embryogenesis, comprising the formation of the entire human being sans the bones. The muscles, tendons, central nervous system and nerves are all there as an oceanic continuum of tissues in which the bones make appearance as an island here, island there, in a staggered fashion. The shoulder muscles, ranging from the massive trapezil to the slender coracobrachialls are all there before the scapula and the humerus appear. This clearly means that, in reality, the humerus is attached to deltoid, the clavicle forms in the path of "supraclavictilar" nerves, and all the bony cases -skull, orbit, vertebral canal-develop round their preformed contents. The same sequence - a soft-tissue organ developing an island of ossification -applies to the formation of *os cordis, os penis* or *os sclerae.*

The ontogenic change from softness to hardness is certainly a repetition of the phylogenic change from invertebrateness to vertebrateness. (The largest invertebrate, the squid, is a massive powerful marine animal, 30'-80' in length, many tons in weight, and unmatched in its rapid swimming by jet-propulsion. It is thus larger and more powerful than many a vertebrate animal. The squid eye is considered the most perfect and beautiful eye, measuring 30-40 cms., in diameter. Being an invertebrate does not seem to be a handicap, nor being a vertebrate, an asset). When the soft interior of a newt or a salamander got ossified, the earliest fish was born. This bony fish then evolved further into two main groups-the purely cartilaginous fishes the sharks, and the cartilage-cum-bony fishes, reptiles, and finally birds and mammals. Each vertebrate begins its career as a pure invertebrate.

If the above logic holds water, we may be able to demonstrate the islandish nature of bone, to demonstrate its arrival late in life of a tissue, to divest bone of the myriad of assumed attachments of muscles, tendons and ligaments. All this is possible, as follows.

:: Material and method

Cadeveric parts, divested of the skin, were immersed for a period of 34 weeks in a decalcifying solution made up of 10% Nitric or Hydrochloric acid. Sufficient decalcification was indicated by the bendability of tibial or humoral midshaft or the ilium. The parts were then dissected to discover the nature of bones. The following observations are reproducible and bear out the logical preamble above.

:: Observations

1. Bone stands apart:

On inspection of the dissected parts, in longitudinal or transverse sections, the most consistent feature was the continuity of all the soft tissues standing in contrast to the manifest isolatedness of bone. It required the rounded tip of the gloved finger to find the plane between a bone and its ambiant tissues. When the finger was navigated round about the entire bone, the whole bone-cortex and medulla intact - could be levered out, leaving its case intact and flush with the peri-osseous tissues (See [Figure:1]). In the vertebral region, or the foot, the blunt tip of the forceps could lever out the vertebral centrum or the calcancum out of the casing.

II. Articular cartilage, free from the bone, is anchored all around:

In absolute contrast to the "articular" ends of a bone, its articular cartilage, standing clearly separate from the bone and only abutting on it, is continuous with the soft tissue casing.

Taking the knee as an example, its bones, femur and tibia are each housed in respective casing. The upper wall of the femoral casing is the articular cartilage of the femoral head, and the lower wall is the articular cartilage over the femoral condyles, the whole "femur" lying free in between. So for the tibia. The knee joint cavity, thus consists of its capsule as the side walls and the femoral condylar cartilage as its roof and the tibial plateau's cartilage as its floor, (See [Figure:2]).

Microphotographs of the articular cartilage show it to be continuous (See [Figure:3]) with the surrounding soft tissue. The nutrition of an articular cartilage should be little less of a problem given the fact that it is one continuous thing with the entire soft tissue casing.

III. Joint ligaments are attached to cartilage and not to bone:

The cruciate ligaments of the knee and the round ligament of the femoral head are clearly one with the articular cartilage and through it with the soft tissue casing, having NOTHING at all to do with the bone (See [Figure:4], [Figure:5]). The same holds true for all the capsules and the periarticular ligaments.

IV. Vertebral column is not what we thought it to be (See [Figure:6])

The entire vertebral column, through the revised view, turns out to be like a sock filled with carrom-strikers and carrom coins. The strikers, representing the intervertebral disc, are circumferentially attached to, and microscopically also one with the sock. Between two strikers is a coin, albeit, much taller than the striker, that fills in the space in such a way that the sock remains free anteriorly and posteriorly to constitute the so-called anterior and posterior longitudinal ligaments.

V. Tendons terminate nowhere:

The tip of a tendon apparently looks like a point where the tendon fibres have zeroed in onto a specific bony point. No fallacy could be greater. The tendons of the long flexors and extensors of the fingers/toes were attached to no bone, and were imperceptibly merging into the soft tissue. As a very illustrative example, the tendons of tibialis posterior, tibialls anterior and the peroncus longus met one another to become continuous with each other at a point at the base of the first metacarpal (See [Figure:7]).

VI. Cortical bone is condensed spongy bone:

[Figure:8] shows tibia removed from its casing. How interesting that it still looks very much like the tibia. [Figure:9] shows X-ray of the same taken with a beam used for X-raying of soft tissues. The shadow of the decalcified tibia in density- is close to that of the soft tissue of the fingers that are holding it, and quite distinct from the bones of those fingers.

A bare-handed study of this tibial specimen showed that the cortical bone is Just like the spongy bone, save that at the cortex the sponge is closely packed. Much as the spongy bone can be pulverised by fingers, so can be cortical bone be reduced to a fine powder. The external surface of the bone, in this case of the tibia, is but the compacted spongy bone reduced into a flat surface by the pressure of the soft-tissue casing in which the bone is contained.

:: Discussion

There are a number of corollaries to the above bone-and-jointperspective.

1. Continuity of all non-osseous tissues:

From head-to-foot, dorsoventrally and side-to-side, there is an uninterrupted continuity of tissues, a reflection of the fact that the entire embryo sprang from a single cell, the zygote. In a coronally or sagittally sectioned head, a tug on the tongue could move the dural folds and vice versa.

2. Nature of a bone:

Take an inflatable toy made of a collapsible, rollable plastic but capable of assuming the shape of a duck, a rabbit or a camel on being pumped in with air. A tubeless tyre of a car is flat without air, but on being filled in with air, it assumes its functional shape. In the body, a bone as such is like the air, being separate and separable from its casing provided by all the soft tissues around. In a way, it is like the air itself that assumes the shape of the plastic toy or the tyre.

Any bone, large or small, flat or long, is a calcified unit of tissue that rigidly, strongly and almost incollapsably fills in a casing provided by the soft tissues around, so that both the casing and bone assume a characteristic shape. The so-called ligaments, muscles and tendons are an integral part of the soft tissues and seem to be attached to the bone, but in fact are in no way so. This would explain why the radiological outline of a bone, despite its myriad attachments is so streamlined and smooth (See [Figure:10]).

As a building material, bone has naturally been compared to steel, having many of its qualities without having its weight or bulk. In the absence of the bone's attachment to any fascia, fibres, muscles, tendon, ligament or cartilage, the bone serves as a single body of cavernous tissue that is a meeting place of solid, liquid and air, a confluence that allows it to obey hydrodynamics and pneumodynamics that render any impact or compression to be transmitted equally in all directions. No wonder that a single femoral head, in an average person, can easily withstand a compression load of as much as 3600 pounds.

3. Nature of a joint:

The true cavity of a synovial joint is forme by its capsule and the two attached cartila ginous plates. Being an enclosed system con taining synovial fluid, it obeys Pascal's La that serves to preserve the integrity of the joint both at the capsular and articular levels.

4. Muscles - no origin or insertion:

A muscle is attached to nothing, bein overlaid over a continuum of collagen. At best a muscle can be said to have two ends - convergent/divergent, upper/lower, proximal/distal, medial/lateral, and so on.