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# EUGENE MARKLEY LANDIS 25th President of the American Physiological Society

Creative scientists are likely to prove their talents at an early age. Gene Landis was born in New Hope, Pennsylvania, in 1901 and his first two publications, entitled "Drosophila and Mendel's Law" and "An amicronucleate race of Paramecium Caudatum" appeared in 1919 and 1920; you, gentle reader, may perform the subtractions. By 1927 "EML" had collected four academic degrees from the University of Pennsylvania, including an M.D. and a Ph.D. More importantly, by 1930 he had published a series of brilliant papers on capillary pressure and capillary permeability in the American Journal Of Physiology (1,2,3,4,). In later years Gene Landis contributed to the American Physiological Society in many ways but the Society can take greatest pride, and Gene the greatest satisfaction, from these classic papers. August Krogh, in his 1928 revision of The Anatomy and Physiology of the Capillaries, noted the very unsatisfactory state of knowledge regarding capillary permeability prior to Gene Landis' studies and wrote as follows: "...the situation has now been wholly changed by the brilliant work of E.M. Landis ... whose methods open up the possibility of an intimate understanding of capillary physiology far beyond anything to be imagined before." The "intimate understanding" of which Krogh spoke, is today the basis of everyday teaching in physiology and the original papers, including the 1934 article in Physiological Reviews, (5) remain as models of beautiful scientific writing.

In 1929 EML was awarded a Guggenheim Memorial Foundation Fellowship and for the next two years he worked with August Krogh in Copenhagen and with Sir Thomas Lewis is London. This association with the elite of experimental zoology and physiology on the one hand and clinical research on the other, was no accident. Indeed, it reflects most accurately Gene's interests and scientific philosophy; few people in our generation have been able to move so easily and productively between biology-for-itsown-sake and clinical medicine. In a recent letter, Gene Landis puts it more modestly, "... my past as a dilletante and perpetual amateur from zoology to medicine and from physiology to biology, is the only consistency I can discover."

After returning from Europe in 1931, EML wore a clinical hat for twelve years, first at the University of Pennsylvania and then as Chairman of the Department of Medicine at the University of Virginia. During this period, his chief research interests and accomplishments involved capillary permeability and fluid exchange as measured by plethysmography in human extremities, (6,7) but he also made the first accurate measurements of the molecular weight of inulin (8) and the first renal clearance measurements of Diodrast in humans (9). He was one of the first investigators to verify unequivocally Tigerstedt and Bergman's long-disputed discovery of renin in kidney extracts, and thus began to establish the pathogenetic role of renin in renovascular hypertension (10).



In 1943 EML returned to "pure" physiology as the third George Higginson Professor of Physiology at Harvard Medical School, succeeding Henry Pickering Bowditch and Walter B. Cannon. World War II was raging and EML had the difficult task of starting a new department with double-duty teaching under wartime conditions. At the same time, he was President of the American Society for Clinical Investigation and he had continuing responsibilities to war research with the Committee on Aviation Medicine in Washington. During this period, the American Physiological Society suspended its normal activities but as soon as the war was over, EML was drafted into the affairs of the society. He served on Council from 1947 to 1951 and was elected President in 1952. The first APS Newsletter was published while EML was President and of course this later developed into The Physiologist. No account of EML's Presidency would be complete without mentioning the APS Gavel. Wallace Fenn, in his Third Quarter History of APS, gives the following account:

At the close of the last Council meeting during his presidency, Dr. Landis entertained members of the Council at dinner and presented to his successor a gavel which he had made with his own hands out of wood historically connected with Dr. H.P. Bowditch and Dr. Walter B. Cannon. It is satisfying to know that the Society had a President who could not only cannulate an individual capillary and measure the pressure inside but could also turn a lathe to make a gavel. Later Dr. (Louis) Katz had a historic box made to hold this gavel and a historic brass plate was added to the cover by Dr. (Hallowell) Davis.

More complete accounts of EML's gavel can be found in *The Physiologist 1*:31 (1958) and *2*:7 (1959).

Over the long term EML's most important post-war contribution to APS stemmed from the stimulus he provided for the young people he attracted to his own department and his part in creating an environment where they flourished and became themselves worthy contributors to APS. No less than six presidents of APS "grew up" as members of EML's department. More important, perhaps, are the Bowditch Lectureships which represent the highest honor APS can bestow on a young physiologist. Of the first 15 Bowditch lecturers (between 1956 and 1971) no less than eight were selected from young people who had done highly original and independent work in EML's department. What greater tribute could there be to an unselfish head of a department of physiology?

The period during which EML served as head of department was an extraordinary one in the history of science. Research changed from being a joyous, spare-time privilege of a university teacher to a driving professional career. The explosive growth of government support for research enabled young investigators to create specialized research empires without regard for departmental or other academic responsibilities. In this heady atmosphere EML retained the voice of reason, integrity and humility. He was surrounded by prima donnas, real or potential, but he was (and still is) a master at controlling their inflationary tendencies while at the same time encouraging their creative ones. When asked for unreasonable technical assistance by a young colleague, Gene responded that some of his best ideas occurred when he was washing his own glassware.

From his father, a teacher of classics, Gene gained an appreciation of the beauty of well-written prose and the precise use of language. These skills, coupled with his patience, his understanding, and his unusual breadth of knowledge, made him a renowned editor, first of the *Journal of Clinical Investigation* and later of *Circulation Research*. Gene received many honors over the years including membership in the American Academy of Arts and Sciences and the National Academy of Sciences. He was the recipient of the John Phillips Memorial Medal of the American College of Physicians, honorary degrees from Harvard and Yale, the Gold Heart Award of the American Heart Association, and honorary membership of the Harvey Society and the Society Argentina de Biology. However, his greatest joy has been his close-knit family--his charming wife Betty, his daughter Barbara, his grandchildren, and his son-in-law, an engineer at IBM, under whose tutelage Gene started a new career in modern electronics on his retirement from Harvard while, at the time, serving as adjunct Professor of Biology at Lehigh University.

> John R. Pappenheimer A. Clifford Barger

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# William Harvey and the Physiology of Reproduction

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It is generally imagined that upon notification of his election, a new President of the American Physiological Society immediately focuses the bulk of his attentions upon the affairs of the organization for which he will soon take responsibility. I hope that you won't be too disappointed to learn that such is really not the case. In fact, what first springs to his mind and looms inexorably larger as his tenure progresses, is the inevitable dénouement of his service: the Past President's address. The subject of his discourse and the manner of its presentation at a convivial, post prandial gathering such as this one, become less a challenge than a torment. There are few things to say about Physiology and the American Physiological Society that haven't already been said on more than one occasion. Hallowell Davis' Presidential Message of 1958, for example, anticipated every problem which confronts us today and his proferred solutions are as applicable now as they were then, if for no other reason that little of gualitative substance has changed in the interim. Perhaps this would not be so had we paid more attention to what he had to say but such is the fate of presidential addresses.

In thinking about my own, I vaguely considered the fact that I may have been the first President of our Society thought by some to be a reproductive physiologist, but molding this realization into an after dinner speech was quite another matter. Imagine my delight, therefore, when browsing in the excellent Historical Collection of our library I chanced upon an original edition of a major opus on the reproduction of animals written by none other than William Harvey. I confess this discovery with no little embarrassment because as a professional physiologist of long standing, I should have known that Harvey, the father of our Science, had produced this tome on reproduction. I need not add therefore, that I approach the subject but as an ingenuous enthusiast and not as a historian, philosopher, or scholar of any sort.

"Exercitationes de Generatione Animalium," or "Exercises on the Generation of Animals," as the work is called, was published simultaneously in London and Amsterdam in 1651 when Harvey was 73 years old, nearly a quarter of a century after the appearance of De Motu Cordis. It was translated into English in 1653 but I availed myself of a later, eminently readable english translation by Robert Willis published in 1847,\* the only other one extant.

It is a ponderous treatise, 568 pages of small print, five times longer than de Motu Cordis by some accounting, and is comprised of seventy-two chapters or "exercises" to which are appended essays on parturition, on the fetal membranes and on conception. In it Harvey discourses at length on every aspect of reproduction known to him, an awesome inventory indeed.



Fig. 1. Original edition of the De Generatione and its more famous antecedent.

The Generation, I am sorry to say, is often a tedious, repetitive work and one impossible to summarize or to encapsulate or even to sample adequately. It appears to be the product of a lifetime of study, of work and of contemplation, begun when Harvey was still a student in Padua where his teacher Fabricious produced a major treatise on the embryology of the chick, a subject which also forms the greater part of Harvey's opus. The volume appears to be a compendium of essays written at different periods, some quite formal, others less so, and not always in order. At times its style is vaguely reminiscent of Claude Bernard's "Introduction to Experimental Medicine" and of his Cahier Rouge. It is of interest that while Bernard attempts to reject vitalism in contemplating the wondrous ways of living things and Harvey invokes the Divinity, both use much the same words to describe that which they don't fully understand, phrases such as "vital properties" and "vital forces."

Harvey's efforts to comprehend the most challenging attribute of animals, the reproduction of their own kind have quite understandably not generated the adulation accorded De Motu Cordis; in fact, rather the contrary is true. In my view his work on The Generation of Animals has been judged with undue harshness by the few who have chosen to comment on it. Granted he didn't solve the mystery of animal reproduction as he had that of the circulation of the blood but such a feat was not humanly possible given the tools at Harvey's command. Unable, without the proper facts to apply the force of his unique intellect to the elucidation of what still remains one of the most vexing problems in biology, he often resorts to philosophy, an exercise which has had little impact on the subsequent course of our discipline. But Harvey was acutely aware of his shortcomings as an explicator of the generation of life and it appears that he had no intention of publishing his voluminous thoughts on the matter. It is only with the greatest reluctance that he succumbed to the blandishments

Past President's Address, Fall Meeting, Ontario, October 14, 1980.

<sup>\*</sup>The Works of William Harvey, M.D. The Sydenham Society, London, 1847.

of his good friend Sir George Ent and permitted him to take charge of his manuscripts for publication. Dr. Ent describes the encounter as follows: "Making many difficulties at first, urging among other things that his work must be held imperfect, ... I nevertheless prevailed at length, and he said to me, 'I entrust these papers to your care with full authority either to speedily commit them to the press, or to suppress them til some future time.' Having returned him many thanks, I bade him adieu, and took my leave feeling like another Jason laden with the golden fleece. On returning home I forthwith proceeded to examine my prize in all its parts and could not but wonder with myself that such a treasure should have lain so long concealed and that whilst others produce their trifles and emptinesses with much ado, their messes twice, aye, a hundred times heated up, our Harvey should set so little store by his admirable observations."

# A N A T O M I C A L EXERCITATIONS,

GENERATION Of Living Creatures:

To which are added Particular Discourses, of Births, and of Conceptions, &c.

By WILLIAM HARVEY, Doctor of Physick, and Professor of Anatomy, and Chirurgery, in the COLLEDGE of Phylicians of LONDON.



# LONDON,

Printed by James Young, for Ostavian Fulleyn, and are to be fold at his Shop at the Sign of the Rofe in St. Pauls Churchyard. 1653.

Fig. 2. Title page of first english translation of De Generatione.

A piece written on the occasion of the 400th Anniversary of Harvey's birth provides an example of the injustice generally accorded to the Generation. In it its author states: "Harvey's downfall really springs from the fact that he adhered too closely to the conventional Aristotelean views on reproduction, he freely admits that Aristotle was his General, and that his former teacher, Fabricious, was his Guide." It seems to me that these admissions of fealty were but professions of modesty assisted perhaps by an element of political prudence at a time when even in England, rejection of the accepted teachings of the masters was viewed by some as bordering on blasphemy. In fact, Harvey as we shall see, repeatedly challenges and successfully overturns some of Aristotle's most influential views on reproduction. He also takes a seemingly perverse delight in his continual and at times intemperate attempts to prove Fabricious wrong. His tone in this context often borders on the vicious and even becomes offensive on occasion. One gains the impression that his protestations notwithstanding, Harvey felt deep rancor for his old master for reasons which are not clear to me. In his assaults Harvey is often wrong, the insights of his teacher being correct in retrospect. But Harvey is invariably an impeccable observer and his descriptions of embryonic development, of reproductive anatomy and of reproductive behavior are faultless. When armed with the correct facts the great power of his reasoning is just as trenchant in this work as in De Motu Cordis. A case in point is his analysis of the hatching of the hen's egg.

He begins by an attack on Fabricious. "Now" he says "we must not overlook a mistake of Fabricious, and almost every one else in regard to this exclusion or birth of the chick. "Let us hear Fabricious:" he continues, and quotes directly from his former master's interpretation of what transpires during this process. It turns out that Fabricious believed, along with Aristotle and Hippocrates among others that at the time of hatching, the chick signals to its mother that it is ready to emerge from the egg, by beginning to chirp. In the words of Fabricious as quoted by Harvey, "the hen hearing the chirping of the chick within, and knowing thereby the necessity of now breaking the shell in order that the chick may enjoy the air which has become needful to it, or if you will, you may say, that desiring to see her dear offspring, she breaks the shell with her beak."

Harvey sardonically continues: "All this is stated pleasantly and well by Fabricious, but there is nothing of solid reason in the tale. For I have found by experience that it is the chick himself and not the hen that breaks open the shell, and this fact is every way in conformity with reason. For how else should the eggs that are hatched in dunghills and ovens, as in Egypt and other countries, be broken in due season, when there is no mother present to attend to the voice of the suffocating chick and to bring assistance to the petitioner? And how again, are the eggs of sea and land tortoises, of fishes, silkworms, serpents, and even ostriches to be chipped? The embryos in these have either no voice with which they can notify their desire for deliverance, or the eggs are buried in the sand or slime where no chirping or noise could be heard. The chick, therefore, is born spontaneously and makes its escape from the eggshell through its own efforts.' But Harvey, not resting his case there, goes on:

"When the shell is first chipped, the opening is much smaller than accounts for the beak of the mother, but it corresponds exactly to the size of the bill of the chick, and you may always see the shell chipped at the same distance from the extremity of the egg, and the broken pieces, especially those that yield to the first blows, projecting regularly outwards in the form of a circlet. But," he continues, "as any one on looking on a broken pane of glass can readily determine whether the force came from without or from within, by the direction of the fragments that still adhere, so in the chipped egg it is easy to perceive, by the projection of the pieces around the entire circlet, that the breaking force comes from within. And I myself... hearing the chick scraping against the shell with its feet, have actually seen it perforate this part with its beak, and extend the fraction in a circlet like a coronet."

Harvey readily admits that the chick may chirp in the egg and willingly concedes that the chirping may be supplicating in tone but adds that it does not necessarily follow that the shell is broken by the mother.

With this brief argument Harvey totally demolishes a view promulgated for a millenium by the most revered and illustrious savants of antiquity and by his own teacher.

If there is a central issue which courses throughout the De Generationes and which Harvey repeatedly addresses, albeit in vain, it is the problem of fertilization or conception. Aristotle believed that the conceptus was formed in the uterus from an admixture or coagulum of menstrual blood and semen. The view of his contemporaries on the matter is described by Harvey himself as follows: "during intercourse the male and female dissolve in one voluptuous sensation, and eject their seminal fluids into the cavity of the uterus, where that which each contributes is unified with that which the other supplies, the mixture having from both equally the faculty of action and the form of matter." This mixture was held to form the rudiments of the embryo in the uterus. Harvey rejects all of these assertions. He says: "But the hen neither emits any semen during intercourse, nor sheds any blood into the cavity of the uterus and that the egg is not formed in the mode in which Aristotle supposed a conception to arise, nor as physicians imagine, from a mixture of the seminal fluids; as also that the semen of the cock does not penetrate into, nor is attracted towards, the cavity of the uterus of the hen, is all made manifestly clear by this one observation, namely, that after intercourse there is nothing more to be found in the uterus, than there was before the act... and what has hitherto been handed to us from all antiquity on the generation of animals, is erroneous."

Of the female contribution at intercourse he wrote: "...I am greatly surprised how physicians, particularly those among them who are conversant with anatomy, should pretend to support their opinions by means of two arguments especially, which rightly understood seem to prove the opposite, viz., from the shock and resolution of the forces and emissions of fluid which women at the moment of the sexual orgasm frequently experience, they argue that all women pour out a seminal fluid, and that this is necessary to generation." Harvey goes on, "But passing over the fact that the females of all the lower animals, and all women, do not experience any such emission of fluid, and that conception is nowise impossible in cases where it does not take place, for I have known several, who without anything of the kind were sufficiently prolific, and even some, who after expriencing such and emission and having had great enjoyment, nevertheless appeared to have lost somewhat of their wonted fecundity; and then an infinite number of instances might be quoted of women who, although they have great satisfaction in intercourse, still emit nothing, and yet conceive." "Even so," Harvey continues in astonishment at the intellectual density of his contemporaries "... the fluid emitted is discharged, cast out, and is particularly abundant about the clitoris and orifice of the vulva, that it is seldom poured out within the vulva, never within the uterus, and so as to be mingled with the semen of the male ... But how shall we suppose that to be of use internally which is discharged externally? Or shall we say of this humour, as if bidding the uterus farewell, is

taken to the verge of the vulva, that it may then be recalled with greater favour by the uterus?"

He continues: "Meantime it is certain, that the egg of the hen is not engendered from any such discharge of fluid during sexual intercourse, although after connection, and brimful of satisfaction, she shakes herself for joy, and, as if already possessed by the richest treasure, as if gifted by supreme Jove the preserver with the blessing of fecundity, she sets to work to preen and ornament herself."

Just as Harvey was unable to find the supposed female seminal component of the conceptus in the uterus after intercourse he also failed to find any trace of the male semen.

Now this was a much more troublesome matter because Harvey obviously knew that the semen is injected into the female reproductive tract during coitus and it was equally clear to him that coupling of the female with the male was necessary for conception. But the manner in which the male fertilizes the egg eluded him and became a veritable obsession to which he returns again and again, from the beginning of his treatise to the end. The acute frustration occasioned by his failure to resolve this seemingly simple problem is evident throughout and is, of course, attributable as you have already guessed to his inability to see or to imagine spermatozoa.

Harvey's thinking on the origins of the conceptus is largely based on his studies of the domestic hen and the development of the chick from her eggs. He begins, with the prescient, albeit not entirely original conclusion that "... all animals whatsoever, even the viviparous, and man himself not excepted are produced from ova."

He recognized that the ova originate in the ovary of the hen as structures "vastly smaller than millet seeds ... or the finest grains of sand, almost escaping the power of sight."

Elsewhere he says: "I cannot but express my admiration that such strength should be reposed ... in such insignificant elements, and that it has pleased the omnipotent Creator out of the smallest beginnings to exhibit some of his greatest works. From a minute and scarce perceptible papula springs the hen, or the cock, a proud and magnificent creature. From a small seed springs a mighty tree; from the minute gemmule or apex of the acorn, how wide does the gnarled oak at length extend his arms, how loftily does he lift his branches to the sky, how deeply do his roots strike down into the ground!"

While vascillating at first, Harvey eventually recognized in opposition to Aristotle, that hens can lay perfectly fine eggs in the absence of the male but agreed with him that for these eggs to be fruitful, the hen must mate with the male. One should add parenthetically, that contrary to the Aristotelian view that the imprint of the male on the progeny is far greater than that of the female, which was considered but as the soil in which the male planted his seed, Harvey believed the contribution of both sexes to be equal in this regard. He based his conclusion on the observation of hybrids in which he clearly recognized the features of both parents.

But in what manner does the cock impart fecundity on the egg? As I have already indicated this totally mystified Harvey. He says "... although he (the male) contributes nothing to the matter of the egg; the procreative or plastic force which renders the egg fruitful alone proceeding from the male; none of its parts contributed by him. For the semen which is emitted by the male during intercourse does by no means enter the uterus of the female, in which the egg is perfected; nor can it indeed, by any manner or way get into the inner recesses of that organ, much less ascend as high as the ovary, near the waist or middle of the body, so that besides its peculiar virtue it might impart a portion

of matter to the numerous ova whose rudiments are there contained." His analyses of the problem is further but understandably confounded by the phenomenon now know as delayed fertilization whereby one insemination can fertilize a whole clutch of eggs, a phenomenon correctly described by Harvey as follows: "... And so far as I can myself affirm from my own observation, to wit, that the twentieth egg laid by a hen, after separation from the cock, has proved prolific." He then wonders whether what is occurring in the hen may not be akin to fertilization in fish where a single external insemination fertilizes, at one time, the myriad eggs emitted by the female. He is so taken with this idea that he violates his own dictum that "... many persons, wholly without experience, from the presumed verisimilitude of a previous opinion, are often led by and by to speak of it boldly, as a matter that is certainly known; whence it comes, that not only are they themselves deceived, but that they likewise lead other incautious persons into error." Harvey says: "Nay, what is more remarkable, and indeed wonderful, it is said [Aristotle] that in Persia, on cutting open the female mouse, the young ones still contained in the belly are already pregnant; in other words, they are mothers before they are born! as if the male rendered not only the female fruitful, but also impregnanted the young which she had conceived; in the same way as our cock fertilizes not merely the hen, but also the eggs which are about to be produced by her."

Delayed fertilization in the domestic fowl is well documented but the ova are not fertilized while still in the ovary. They are fertilized one at a time as they are ovulated by sperm, stored in the oviduct, which retain their fertilizing capacity for about 3 weeks as Harvey had indeed demonstrated. They appear to be seguestered in epithelial pockets lining the oviduct but their exact location remains uncertain. Fabricious, in explanation of delayed fertilization, postulated such a storage mechanism in the bursa that bares his name but Harvey disagreed emphatically with this view because, as he says "... neither there nor anywhere else in the hen, have we been able to discover this stagnant semen of the cock." He goes on to say: "For the cock does not confer any fecundity on the hen, or her eggs, by the simple emission of his semen, but only in so far as the fluid has a prolific quality, and is imbued by a plastic power; that is to say, a spiritual, operative, and analogous to the essence of the stars" ... "He (the male) introduces his semen, imbued as it is with the spirit and the virtue of a divine agent, such as, in a moment of time, performs its functions, and conveys fertility."

He likens this "prolific" power of the semen to a contagion which infects the hen and render her eggs fertile, the same way as he says "... medical men observe contagious diseases such as leprosy, lues venera, plague, phthisis, to creep through the ranks of mortal men, and by mere extrinsic contact to excite diseases similar to themselves in other bodies ...".

Elsewhere he asks: "What is this transitory thing, which is neither to be found remaining, nor touching, nor contained, as far as the senses inform us, and yet works with the highest intelligence and foresight, beyond all art, and which even after it has vanished, renders the egg prolific, not because it now touches, but because it formerly did so."

Some 250 pages later Harvey despairs, "Many observations have been made by me which would easily overthrow the opnions I have mentioned, so easy is it to say what a thing is not rather than what it is...if that which is called by the commn name of 'contagion' as arising from the contact of the spermatic fluid in intercourse, and which remains in the woman (without the actual presence of the semen) as the efficient of the future offspring, if I say, this contagion is not of the nature of any corporeal substance, it follows of necessity that it is incorporeal. And if on further enquiry, it should appear that it is neither spirit or demon, nor soul, nor any part of the soul, nor anything having a soul, as I believe can be proved by various arguments and experiments, what remains, since I am unable myself to conjecture anything besides, nor has anyone imagined aught else even in his dreams, but to confess myself at a standstill?"

All these reflections which are repeatedly elaborated upon at great length, are the consequence as I have already noted, of Harvey's inability to imagine the existence of the spermatozoa. Aristotle and Fabricious on the other hand, came very close to doing so, perhaps because they lacked Harvey's commitment to the scientific method which demanded actual observation as a starting point. Yet Harvey had no problem with imagining the existence of the capillaries without ever having seen them.

One may be tempted to conclude that Harvey would have arrived at the appropriate conclusion regarding the relation between insemination and fertilization had he possessed a microscope. This may well be so, but it should be recalled that spermatozoa are extremely difficult to find in the oviduct of the hen and were not in fact seen there until the 1940's, nearly 300 years after van Leeuwenhock's first description of mammalian sperm.

It is of interest that Harvey, at least on occasion, was better guided by teleology than by reason. Although he personally observed that fertilization could occur for some 3 weeks after mating, he was somewhat ambivalent about accepting the probably incorrect view of the ancients and of Fabricious himself, that one or two matings sufficed to fertilize all the eggs that a hen could lay in a year. I say probably incorrect because certain strains of domestic fowl are known, like turkeys, to reproduce parthenogenetically. The phenomenon of parthogenesis, incidentally was known to Harvey and he described it at some length in the Generationes. How confusing all of this must have seemed to him. It certainly is to me. In any case, he says at one point: "...that hens should continue for a whole year to lay prolific eggs after a few addresses of the cock, appeared to me by no means probable: for, had a small number of contacts sufficed for the purposes of generation during so long a period, nature which does nothing in vain, would have constituted the males among birds less salacious than they are; nor should we see the cock soliciting his hens so many times a day, even against their inclination...which surely nature had never permitted unless for purposes of procreation." Harvey concludes: "It did not therefore appear likely that a few treads, in the beginning of the year, should suffice to render fertile the whole of the eggs that are to be laid in its course."

He promises to continue this discourse in his "treatise on the Loves, Lusts and Sexual Acts of Animals" but most unfortunately, this piece has been lost to us forever or was never written.

In any case, in an earlier discussion Harvey associates the frequency of mating with the genital apparatus of the male. He notes that the cock makes frequent genital contact with the hen "her cloaca being exposed for the occasion, is anointed with genital fluid, which consequently does not require a penis for its intromission." He contrasts this behavior with that of infrequent copulators who, in his words "are long in connection." Among these he cites the ostrich, the swan, the goose and the duck and claims that these birds in contrast to the fowl are endowed with large penile appendages. "In the male ostrich" he says, "I have found within the pudendal orifice a very large glans, and the red body of the penis, as we discover them within the prepuce of the horse, resembling a deer's or a small neat's tongue in form and magnitude; and I have frequently observed this organ, rigid and somewhat hooked during the coitus, and when entered into the vulva of the female, held for some considerable time there without any movement: it was precisely as if the two creatures had been fastened together with a nail." Further, he recounts "In a black drake I noticed the penis of such a length that after intercourse it trailed on the ground, and a fowl following, pecked at it greedily, thinking it an earth-worm, as I imagine, so that it was retracted more quickly than usual." If your confidence in Harvey's observational exactitude is somewhat shaken as was mine by this description of avian penises, please be reassured; such organs are common knowledge to ornithologists albeit totally unknown to me before this reading.

Not all is sex in the De Generationes for in this volume Harvey describes an experience which eclipses that of William Beaumont. I shall quote it in its entirety for the benefit of those of you who are as unaware of it as I was.

"A young nobleman, eldest son of the Viscount Montgomery, when a child, had a severe fall, attended with fracture of the ribs of the left side. The consequence of this was a suppurating abscess, which went on discharging abundantly for a long time, from an immense gap in his side; this I had from himself and other credible persons who were witnesses. Between the 18th and 19th years of his age, this young nobleman, having travelled through France and Italy, came to London, having at this time a very large open cavity in his side, through which the lungs, as it was believed, could both be seen and touched. When this circustance was told as something miraculous to his Serene Majesty King Charles, he straightway sent me to wait on the young man, that I might ascertain the true state of the case. And what did I find? A young man, well grown, of good complexion, and apparently possessed of an excellent constitution, so that I thought the whole story must be a fable. Having saluted him according to custom, however, and informed him of the king's expressed desire that I should wait upon him, he immediately showed me everything, and laid open his left side for my inspection, by removing a plate which he wore there by way of defence against accidental blows and other external injuries. I found a large open space in the chest, into which I could readily introduce three of my fingers and my thumb; which done, I straightway perceived a certain protuberant fleshy part, affected with an alternating extrusive and intrusive movement; this part I touched gently. Amazed with the novelty of such a state, I examined everything again and again, and when I had satisfied myself, I saw that it was a case of old and extensive ulcer, beyond the reach of art, but brought by a miracle to a kind of cure, the interior being invested with a membrane, and the edges protected with a tough skin. But the fleshy part, (which I at first sight took for a mass of granulations, and others had always regarded as a portion of the lung,) from its pulsating motions and the rhythm they observed with the pulse, when the fingers of one of my hands were applied to it. those of the other to the artery at the wrist - as well as from their discordance with the respiratory movements, I saw was no portion of the lung that I was handling, but the apex of the heart! covered over with a layer of fungous flesh by way of external defence, as commonly happens in old foul ulcers. The servant of this young man was in the habit daily of cleansing the cavity from its accumulated sordes by means of injections of tepid water; after which the plate was applied, and, with this in its place, the young man felt adequate to any exercise or expedition, and, in short, he led a pleasant life in perfect safety.

"Instead of a verbal answer, therefore, I carried the young man himself to the king, that his majesty might with his own eyes behold this wonderful case: that, in a man alive and well, he might, without detriment to the individual, observe the movement of the heart, and, with his proper hand even touch the ventricles as they contracted. And his most excellent majesty, as well as myself, acknowledged that the heart was without the sense of touch; for the youth never knew when we touched his heart, except by the sight or the sensation he had through the external integument.

"We also particularly observed the movements of the heart, viz.: that in the diastole it was retracted and withdrawn; whilst in the systole it emerged and protruded; and the systole of the heart took place at the moment the diastole or pulse in the wrist was perceived; to conclude, the heart struck the walls of the chest, and became prominent at the time it bounded upwards and underwent contraction on itself."

The late Loren Carlson began his address in 1969 by saying: "Nothing is paster than a past president." Harvey put it more colorfully in describing the fate of roosters beyond their fruitful years. He tells us that when they are in their prime "It is surprising to see with what passion they are inflamed; and then how trimly they are feathered, how vainglorious they show themselves, how proud of their strength, and how pugnacious they prove! But, the grand business of life accomplished, how suddenly, with failing strength and pristine fervour quenched, do they take in their swelling sails... and like the veteran soldier, by and by crave discharge from active duty."

Thank you and good night.

#### MEMBER CONTRIBUTIONS

Contributions to the Society may be made to the General Operating Fund or other designated purpose. The donor may commemorate an event or memorialize an individual.

We gratefully acknowledge the contributions received from the following Emeritus Members:

Kenneth S. Cole J.R. Elkinton Henry D. Lauson M.C. Shelesnyak Reginald M. Taylor Clinton N. Woolsey

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#### Abstracts Invited for Fourth Annual Workshop on PULMONARY PHYSIOLOGY AND FUNCTION TESTING IN SMALL LABORATORY ANIMALS

Satellite Conference to the Annual Meeting of the AMERICAN THORACIC SOCIETY

Co-sponsored by

#### AMERICAN PHYSIOLOGICAL SOCIETY

US. ENVIRONMENTAL PROTECTION AGENCY

# in cooperation with

Lifelong Education Programs, MSU

#### May 9, 1980

### The Kellogg Center for Continuing Education Michigan State University East Lansing, Michigan

The one day program will concern the current state of the art in pulmonary function testing in small laboratory animals (rodents and lagomorphs). Abstracts are requested for a poster symposium which will focus on data obtained during exposure to environmental or occupational pollutants. Emphasis should be given to techniques and data interpretation in order to stimulate discussion. If a large number of abstracts are submitted, abstracts will be selected which are of good quality and contribute to the above theme. Presentation of material at the American Thoracic Society Meeting does not preclude presentation at this symposium. Presentation of work in progress is encouraged.

Abstracts should be typed (double spaced) and should not exceed one  $8\frac{1}{2}$ " x 11" sheet with  $1\frac{1}{4}$ " margins. Deadline for abstract submission to Dr. N.E. Robinson is March 15, 1981.

The poster symposium will be followed by invited presentations on interpretation of data and scaling of pulmonary function measurements. Ample social time will be allowed for informal discussion among registrants.

Further information can be obtained from:

N.E. Robinson	Sandy lannotta
Department of Physiology	American Thoracic Society
Michigan State University	1740 Broadway
East Lansing, MI 48824	New York, NY 10019
(517) 353-5978	(212) 245-8000

The workshop will be held at Kellogg Center on the Michigan State University campus. Taxi and limousine service is available between Lansing Airport and the campus. Overnight accommodations are available at the center (\$27.00 single, \$16.00 each for shared double). Buses will be provided to the ATS convention in Detroit after the workshop on May 9th. Registration fee (\$25.00) includes continental breakfast, lunch and bus fare to Detroit.

#### PHYSIOLOGY CAREER OPPORTUNITIES SYMPOSIM

#### ATLANTA APRIL 13, 1981

Recognizing that the career path for physiologists has been changing in recent years, a suggestion of a special Symposium on this subject arose from Sustaining Associate Members of the American Physiological Society. To attract the widest possible participation, it was proposed that the Symposium be held during the Spring Meeting at a time not to conflict with the scientific program.

Responding to the suggestion, the APS Careers Opportunity Committee, under the chairmanship of Walter C. Randall has developed a Symposium to be held in Atlanta on Monday afternoon, April 13, 1981. The session will be held from 4:30 P.M. to 6:30 P.M. in the Ballroom West of the Atlanta Hilton.

Symposium speakers will discuss physiology career opportunities in industry, government, clinical departments and the basic sciences. Speakers will include Edward H. Blaine, Merck, Sharpe and Dohme; Theodore Cooper, the Upjohn Company; Alfred P. Fishman, University of Pennsylvania; Donald M. Maccannon, National Heart, Lung and Blood Institute; and Thomas M. Saba, Albany Medical School.

An open discussion with the Careers Committee and the speakers will follow the formal presentation. Questions, comments or observations from the audience will also be encouraged. It is hoped that suggestions for study by the APS Careers Opportunity Committee will result from the Symposium.

#### NOTES FROM CAPITOL HILL

The long drawn out appropriations process for FY81 has reached a temporary halt. In mid december, both House and Senate passed a continuing resolution to allow Government to function until June 5, 1981. It has taken almost a month to sort out just what was voted on and what that will mean in NIH. The overall increase for NIH was a modest 4%; money available for extramural research grants is up 11%. New and competing renewal grants will have 15% more funds available, and NIH projects that about 5,000 such grants can be made. All the Institutes did fairly well.

Research training escaped the ignominious end planned by OMB and gained 9% over last year. A few new commitments can be made after the cost-of-living increases are paid.

The fate of these programs for the remainder of the year will depend upon what changes Reagan makes in the Carter FY82 budget. That budget is rumored to contain enough funds now to maintain the new and competing renewal grant at a level of 5,000.

The cast of characters in the new Administration is shaping up slowly. Mr. Schweiker, at HHS, has been a friend of basic research for as many years as he has been in the Senate - Lets hope he continues to be and work to keep him so. The case for basic biomedical research rests in friendly, dedicated, but not spendthrift, hands in the House. There will be a complete change in membership in the HHS Appropriations Subcommittee in the Senate, and some education will be necessary there. I suspect that research training will be in for another hard time at OMB.

> Brian Curtis, Chairman Public Affairs Committee

#### ORGANIZATIONAL MEETING OF THE SECTION ON CELLULAR AND GENERAL PHYSIOLOGY

As described in *The Physiologist* for June 1980, the Council of the Society has mandated the formation of Sections to represent the various interests of the membership. Among these is to be a Section on Cellular and General Physiology. An organizational meeting for the formation of this Section will be held in conjunction with the 1981 Spring meeting, at 8:00 p.m. on Sunday, April 12 in Ballroom West of the Atlanta Hilton.

Membership in this Section is open to all persons with interests in cellular or general physiology, and is not precluded by membership at the same time in other Sections or informal "clubs" that meet with the Society. The purpose of the Section will be to represent through its Steering Committee the interests and concerns of its members to Council and to other committees that are responsible for the various activities of the society. Specifically, the Section will advise the Program Committee on the organization of symposia and other scientific sessions at Society meetings, and will advise the Editorial Board of the American Journal of Physiology: Cell Physiology. The Section will recommend members for appointment to the editorial board of the journal. The Section can be a forum for concerted action in the nomination of councilors or president of the Society. In the event of topical meetings of the Society or FASEB in the future, the Section will be a focus for such topical organization. It is anticipated that the Section will meet at least once per year, most probably at the Federation Meetings.

The agenda for the organizational meeting in Atlanta will include two items. (1) Adoption of a Statemnt of Organization and Procedures. Such Statements for other Sections that have already been formed have been published in *The Physiologist* for October 1980. The Statement for the Cellular and General Physiology Section is being prepared by the organizing committee and will be distributed at the organizational meeting for action. When adopted, the final version will be submitted to Council for approval. (2) Election of a Steering Committee for the Section.

All interested members of the Society are urged to attend the organizational meeting. Persons wishing to join the Section if they have not already done so, may ask the APS Department of Membership Services to add their names to the list of members. If possible please cite your Society ID number (6 digits shown on your mailing label) to ease the task of recording your request.

The Organizing Committee: John Cook (Chair)

Clay Armstrong Richard Berlin Marie Cassidy Bob Fellows John Forte Bob Gunn Sandy Helman Martin Kushmerick Mel Lieberman Peggy Neville Radovan Zak

#### HONORS AND WARDS

**Roger H. Unger,** M.D., Professor of Internal Medicine at the University of Texas Health Science Center at Dallas, and an APS member since 1976, received a rare honor December 12 when he was awarded an honorary doctor's degree (docteur honoris causa) on the 1,000th anniversary of the University of Liege in Liege, Belgium.

The 1,000-year-old university honored Unger for his work on the hormone glucagon and diabetes.

The proposition accompanying the degree discusses his early laboratory work, stating in part: "In 1959-60 he developed a radioimmunological assay for glucagon and used it to determine that glucagon is a hormone and to define its physiological importance in fuel metabolism.

### NEH ANNOUNCES 1981 HUMANITIES SEMINARS FOR PHYSICIANS, NURSES, AND OTHER HEALTH-CARE PRACTITIONERS

In the summer of 1981, the National Endowment for the Humanities will sponsor eight seminars for physicians, nurses, and other health-care professionals.

The program brings them together for a month of full-time study in seminars directed by distinguished philosophers, medical teachers, social scientists, historians, and other scholars at selected colleges and universities throughout the country.

Its purpose is to advance public understanding and use of the humanities by giving professional leaders the opportunity to stand back from their work and explore a wide range of issues of national concern under the direction of scholars in the humanities.

Three seminars are open only to physicians, nurses, public health officials, hospital administrators, and other health-care practitioners. In addition, five Interprofessional Seminars are offered for health-care practitioners and members of other professions.

Topics include ethico-legal issues raised by new developments in genetic science, the political dimension of health care policy, the healer and society in Western culture; and, among Interprofessional Seminar topics, morality and international relations, taste and U.S. popular culture, conflicts between individual values and professional responsibilities, competing rights claims in contemporary society, and Caribbean societies and relations with the U.S.

From 12 to 15 persons attend each seminar tuition-free, receiving a stipend of \$1,200 plus reimbursement for travel. The application deadline is April 13, 1981.

For applications and further information write: Professions Program, Division of Fellowships & Seminars, MS-101, National Endowment for the Humanities, Washington, D.C. 20506



# ARLIE V. BOCK - Physiologist

A Vignette

D. Bruce Dill

Most of Arlie Bock's friends have thought of him as a highly skilled physician; some have called him "Doctor's Doctor." I think of him as a physiologist. When I arrived in Boston in 1925 to work under L. J. Henderson's guidance, he had shifted his attention from Edwin Cohn's Laboratory of Physical Chemistry in the Harvard Medical School (HMS) to Arlie Bock's laboratory in the Massachusetts General Hospital, the MGH, so I was sent there to work with Arlie.

Arlie lost no time in introducing me to the Van Slyke blood gas analysis apparatus, the bicycle ergometer and two Tissots as we called them; one held 120 liters, the other, for exercise, 600. I found I was to work with two brilliant young investigators. One, John S. Lawrence, M.D., Virginia, was a Bradford fellow; he retired recently as professor of medicine at UCLA. The other, Lewis Hurxthal, M.D., Harvard, had an appointment as research physician, 1925-1926. Later he became head of the Department of Internal Medicine, the Lahey Clinic in Boston and on retirement, Senior Research Associate in that clinic.

Arlie himself graduated at Upper Iowa College in 1910 and was admitted to the Harvard Medical School where he graduated in 1915. He went overseas with the Harvard unit of US Base Hospital No. 5. During that time he came to the attention of Roger Lee who commanded the unit. After returning Lee was professor of medicine and a powerful figure in Boston's medical circles. I have quoted from LJ's "Memories" (11) his statement that Roger Lee informed him of Arlie's talents: the two probably had a hand in getting Arlie appointed a Moseley Traveling Fellow to study, 1920-21, in Cambridge with Barcroft.

From Barcroft, he learned techniques for equilibrating blood with suitable gas mixtures at partial pressures of CO<sub>2</sub> that may exist in the body. From analysis of samples of equilibrated blood and of gas in the tonometer, CO<sub>2</sub> dissociation curves were derived. Arlie, in recalling that year, writes, "You might be interested to know that I introduced venepuncture to Barcroft's laboratory."



Fig. 1. In front of the Bulfinch Building, Massachusetts General Hospital, 1926. (Left to right, standing) John S. Lawrence, Lewis Hurxthal, and Bruce Dill. (Sitting) L.J. Henderson and A.V. Bock.



Historical Articles Section Editor: Orr E. Reynolds, APS Associate Editors: Horace Davenport, Department of Physiology, University of Michigan Ralph Kellogg, Department of Physiology University of California, San Francisco

> Arthur B. Otis, Department of Physiology, University of Florida M. C. Shelesnyak, APS

Executive Editor:

Arlie and a Harvard friend, Alfred Redfield, who was spending the same year in Barcroft's laboratory learned that Barcroft was planning a high altitude study in Peru and soon they shared Barcroft's enthusiasm for the expedition. The two of them came back to help organize the expedition and with great enthusiasm for the Barcroft concept that had been immortalized by his, "The Respiratory Function of the Blood."(1).

Barcroft's assistant, J. H. Doggart, was signed up for the expedition and besides Bock and Redfield, four others from the U.S.: H. S. Forbes (who had been in the Harvard unit in France), C. L. Binger, George Harrop (from the Rockefeller Institute), and J. C. Meakins. Sufficient funds were found with LJ's help. The party had a highly successful time at Cerro de Pasco as is clear from the paper Barcroft wrote (2). They were able to study arterial blood by puncture of the brachial artery, a technique first described by Harrop (14), so it was not necessary for a surgeon to expose the brachial artery as had been done on Barcroft earlier (3).

Bock came back from Peru in 1922 filled with enthusiasm for setting up a laboratory in the MGH where clinical and physiological studies could be carried out. He was assigned two rooms in the Bulfinch building, MGH, and with money from the Procter fund, equipped the laboratory not only for the study of patients, but also of healthy men in rest and exercising on the bicycle ergometer. In late 1922 he began a classical study of five cases of diabetic coma including arterial pCO<sub>2</sub>, pH and alkaline reserve before and after recovery incident to administration of insulin which had become available for medical research not long before. The study was completed in February 1923 and was published later that year (9). It caught the attention of Roger Lee who was visiting physician at the MGH; perhaps he called it to the attention of LJ. In this connection Arlie writes, "I am not sure but I think LJ's real interest in our lab was due to the study of 5 cases of diabetic coma published in the *Journal of Medical Research*, July, August, 1923."

There was another publication by Bock and colleagues in 1923 on which LJ depended, for writing in that same year his great paper, "Blood as a physicochemical system II" (16). Bock's paper described carbon dioxide and oxygen dissociation curves of human (Bock's) blood. Included were measurements of the pH, pCO<sub>2</sub>, and total CO<sub>2</sub> and O<sub>2</sub> of arterial blood in rest (10). That paper of LJ's with joint authors, Bock, Field and Stoddard (16) was the cornerstone on which eleven other papers in the series rested. It depended not only on Bock's CO<sub>2</sub> and O<sub>2</sub> dissociation curves but also on the classical paper of Van Slyke, Wu, and McLean (17) in which the chloride shift between red cells and plasma was related to pH and other properties of the blood. The d'Ocagne nomogram that LJ introduced in that paper pictures



Fig. 2. In Arlie Bock's Laboratory, 1926. Arlie on the bicycle ergometer. Observers, left to right, Bruce Dill and Lewis Hurxthal.

the interrrelations in the respiratory cycle between seven variables: free oxygen, total oxygen, free carbon dioxide, total carbonic acid, pH, the volume of red cells and the concentration of anions within and without red cells. During my two years in Arlie's laboratory, five more papers in that series were completed and another field was opened thanks to Arlie's leadership, *the physiology of exercise.* 

Taking part in exercise studies were some other investigators. Hurxthal continued through 1927 but Lawrence left; Følling came from Norway and Van Caulaert from France. John Talbott took a year off from HMS to join us in the first of several papers dealing with "Studies in Muscular Activity." Bock, Dill, and Talbott introduced a mixing chamber between the subject and the gasometer making it possible to measure rate of gas exchange over one-minute periods. Cardiac output during exercise was determined from arterial pCO<sub>2</sub>, from the CO<sub>2</sub> content of oxygenated venous blood obtained by the CO<sub>2</sub> rebreathing method and from rate of CO2 output (6). In the second paper a nomogram was described which permits reading the R.Q. and the "True O<sub>2</sub>" percentage knowing that percent of CO<sub>2</sub> and O<sub>2</sub> in expired air (13). The third paper in the series "Dynamical Changes Occurring in Man at Work," included a large number of observations on each of several subjects: Bock, Van Caulaert, Følling, Dill, and marathoner Clarence De Mar. Included were metabolic rates at many levels of exercise, cardiac output, and derived characteristics of arterial and mixed venous blood (7). The fourth paper in this series and the last to be done at the MGH included deductions from the respiratory quotient during exercise (8). These four papers published in the Journal of Physiology (London) established the reputation of Bock as an exercise physiologist, aroused in me a keen interest in physiology, and cemented a friendship with Arlie that has grown stronger with the years.

In 1927, A. V. Hill visited the laboratory and invited Bock and me to write a third edition of Bainbridge's "The Phsyiology of Muscular Exercise." This was published in 1931 (4); writing it was a valuable experience for both of us.

The Fatigue Laboratory, established in the Fall of 1927, a monument to LJ's bold concept - took much of Arlie's attention although he continued research at his laboratory at the MGH. He was a member of the committee headed by LJ that was responsible for overseeing the Fatigue Laboratory. In 1932, Arlie was a member of our desert party and helped in a study comparing man and dog exercising in desert heat (12). He and I wrote a resume' of physiological observations made in 1932 on man in the desert (5).

Arlie in 1935 became Henry K. Oliver Professor of Hygiene at Harvard University with responsibility for student health. His interest in human physiology never lapsed. He, Clark Heath and other colleagues with support from W.T. Grant, initiated a study of a representative group of Harvard students beginning in their Freshman year. This included physiological, sociological, and psychological characteristics. Heath described some of the findings (15). Study of that same group continues at Harvard. The concept reflects one of Arlie's main interests: why do people stay well rather than why they become ill.

Arlie and I have corresponded regularly in recent years. He gave up mowing his lawn two years ago and now lives with his son's family (50 N. Wachussetts St., Holden, MA 01520) but still writes a good letter with a steady hand at age 91. I'll end with a quotation in which LJ credits Arlie with being "invaluable because he is ideally qualified by industry, initiative, enthusiasm, and immense power of work to do what had to be done."(11).

#### ACKNOWLEDGEMENTS

I am indebted to Lewis Hurxthal for the pictures and for much information about events at Harvard before WWI. Arlie helped me with reminiscences and loaned me his precious last reprint of his paper on acid-base balance in diabetic coma.

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# INSTRUCTIONS FOR APPLYING FOR APS MEMBERSHIP

#### CURRENT APPLICATION FORMS

Most issues of The Physiologist routinely carry one copy of the current application form (following). This form will serve for all categories of membership. Any member desiring to sponsor more than one applicant may use a Xerox copy of this form. Any application submitted on an out-dated form will be redone on the acceptable form.

One application form serves all membership categories. There are, however, specific sets of instructions for each category. Therefore it is essential that sponsors and applicants carefully attend to those instructions specific to their desired category.

#### **GENERAL INSTRUCTIONS**

#### FOR ALL CATEGORIES:

Use only the current application form. Check the box indicating the category of membership for which you are applying. Use the <u>SPECIAL INSTRUCTIONS</u> for that category when filling out the form. Type the Application. Fill out all applicable spaces. Only completed applications will be reviewed.

<u>Alien Residents.</u> Canadian residents should furnish a copy of "Landed Immigrant Status" form. Mexican residents should furnish a copy of their form FM-2.

<u>The Bibliography</u> must be submitted in the form found in the Society's journals. An example of the correct form is:

JONES, A.B., and C.D. Smith. Effect of organic ions on the neuromuscular junction in the frog. <u>Am.</u> J. Physiol. 220:110-115, 1974.

#### DO NOT INCLUDE A CURRICULUM VITAE

Send no reprints.

<u>Deadline Dates</u>: Completed applications received between February 1 and July 1 are considered for nomination by the Council at the Fall Meeting. Applications received between July 1 and February 1 are considered for nomination by the Council at the Spring Meeting. Applications are not complete until all materials, including sponsor's letters, are received.

#### QUALIFICATIONS (Except Students):

The Membership Advisory Committee uses the following 5 categories in evaluating an application:

1. Educational History. Academic degree and postdoctoral training are evaluated and assessed with regard to how closely the applicant's training has been tied to physiology.

- 2. Occupational History. Particular emphasis is given to those applicants who have a full time position in a department of physiology, or are responsible for physiology in another department. Relatively high ratings are given to people with positions in clinical departments and to people functioning as independent investigators in commercial or government laboratories.
- 3. Contributions to the Physiological Literature. This category is of major importance. The applicant's bibliography is evaluated on the basis of publications in major, refereed journals which are concerned with problems judged to be primarily physiological in nature. Emphasis is given to papers published as the result of independent research. Special note is taken of publications on which the applicant is sole author or first author.
- 4. Interest in and Commitment to Teaching Physiology. This evaluation is based on: (1) the fraction of the applicant's time devoted to teaching, (2) publications related to activities as a teacher including production of educational materials, and (3) special awards or other recognition the applicant has received for outstanding teaching effectiveness.
- 5. Special Considerations. This category permits the Membership Advisory Committee to acknowledge unique accomplishments of an applicant. These might be excellence in a specific area, or unusual contributions to Physiology resulting from talents, interest or a background substantially different from the average.

#### SPONSORS:

Primary responsibility for membership rests with the two sponsors who must be regular members of the Society. Sponsors should discuss the appropriateness of the selected category of membership in this Society with prospective applicants.

Each sponsor should write an independent confidential letter about the candidate using the five categories listed above to evaluate the candidate. Furnish an original and 7 copies to the Membership Secretary.

#### CHECK LIST:

- 1. Original copy of application signed by both sponsors.
- 2. Application on a current form, including the bibliography (1 original and 7 copies).
- 3. Mail the original, which has been signed by the two sponsors, plus 7 copies to:

Membership Secretary American Physiological Society 9650 Rockville Pike Bethesda, Maryland 20014

# SPECIAL INFORMATION AND INSTRUCTIONS

# FOR REGULAR MEMBERSHIP

# Bylaws of the Society:

Article III, Section 2 - Regular Members. Any person who had conducted and published meritorious original research in physiology, who is presently engaged in physiological work, and who is a resident of North America shall be eligible for proposal for regular membership in the Society.

#### **Duties and Privileges:**

- 1. Hold Elective Office.
- 2. Vote at Society Meetings.
- 3. Serve on Committees, Boards and task forces.
- 4. Serve on Federation Boards and Committees.
- 5. Sponsor New Members.
- 6. Orally present or co-author a contributed paper and sponsor a non-member authored paper at the Fall scientific meeting.
- 7. Orally present or co-author one contributed scientific paper at the annual Federation meeting or sponsor one paper.
- 8. Receive The Physiologist.
- 9. Receive <u>Federation Proceedings</u>, Public Affairs Newsletters and annual Membership Directory.
- 10. Subscribe to handbooks and periodicals published by the Society at membership rates.
- 11. Register to attend scientific meetings of the Federation and the APS Fall meeting at membership rates.
- 12. Participate in FASEB Member's Life Insurance Program, Disability Program and in Hospital Protection Plan. (For Residents of the United States, its territories or possessions).
- 13. Eligible to receive the Daggs Award.
- 14. Eligible to be selected as Bowditch Lecturer (members under 40 years of age).

# FOR CORRESPONDING MEMBERSHIP

# Bylaws of the Society:

Article III, Section 3 - Corresponding Members. Any person who has conducted and published meritorious research in physiology, who is presently engaged in physiological work and who resides outside of North America shall be eligible for proposal for corresponding membership in the Society.

#### **Duties and Privileges:**

- 1. Serve on Society Committees, Boards and Task Forces.
- 2. Serve as one sponsor of new Corresponding Members (One regular member must be sponsor of a new Corresponding Member).

- 3. Orally present or co-author a contributed paper and sponsor a non-member authored paper at the Fall scientific meeting.
- 4. Orally present or co-author one contributed scientific paper at the annual Federation meeting or sponsor one paper.
- 5. Receive The Physiologist.
- 6. Receive Federation Proceedings, Public Affairs Newsletters and annual Membership Directory.
- 7. Subscribe to handbooks and periodicals published by the Society at membership rates.
- 8. Register to attend scientific meetings of the Federation and the APS Fall meeting at member rates.

# FOR ASSOCIATE MEMBERSHIP

#### Bylaws of the Society:

Article III, Section 5 - Associate Members. Persons who are engaged in research in physiology or related fields and/or teaching physiology shall be eligible for proposal for associate membership in the Society provided they are residents of North America. Associate members may later be proposed for regular membership.

# **Duties and Privileges:**

Same as for Regular Members except for the privilege of:

- 1. Holding Executive Office, or membership on certain committees.
- 2. Voting at Society Meetings.
- 3. Sponsoring New Members.
- 4. Receiving the Daggs Award.
- 5. Selection as Bowditch Lecturer.

# FOR STUDENT MEMBERSHIP

Not all questions on the application form may be appropriate – Please place NA next to any such question.

# Bylaws of the Society:

<u>Article III, Section 7</u> - <u>Student Members</u>. Any student who is actively engaged in physiological work as attested to by two regular members of the Society and who is a resident of North America. No individual may remain in this category for more than five years, without reapplying.

# **Duties and Privileges:**

- 1. Present one contributed paper at the Fall Scientific meeting with the endorsement of the student's advisor.
- 2. Receive The Physiologist.
- 3. Subscribe to Handbooks and Periodicals at member rates.
- 4. Register to attend scientific meetings of the Federation and the APS Fall meeting at student rates.

Submit original and 7 copies of application and supporting documents.

	APPLICANT'S LAST NAME	3
	Date	
9650 Roc	ckville Pike, Bethesda, MD 20014	L Y
MEMBERSHIP AP	PLICATION FOR:	REGULAR
CURRENT MEMBERSHIP CATEGORY; YEAR ELECTED		ASSOCIATE
See Instructions		STUDENT
Name of Applicant:	Middle	Last
Mailing	Birth Date:	
Address	Citizenship:	
	Country of Permanent Resident	* ce:
	Telephone No.:	
* Alien residents of Canada and Mexico see Ge Card number	eneral Instructions. Alien residents of	U.S. enter Alien Registration Receipt
1. EDUCATIONAL HISTORY		
Dates Degree Institution	Major Field	Advisor
2. OCCUPATIONAL HISTORY Present Position: Prior Positions: Dates <u>Title</u> Institution	<u>Department</u>	Supervisor
<u>SPONSORS</u> #1. Name:	#2. Name:	
Mailing Address:	Mailing Address:	
Telephone No. Zip C	ode Telephone No.	Zip Code
I have read the guidelines for applicants and sponso	ors and this application and attest that the	he applicant is qualified for membership
#1 Signature	#2 Signature	
Each sponsor must submit an original and 7 copies	of a confidential letter of recommendat	ion to the Society, under separate cover

3. DESCRIBE YOUR PHYSIOLOGICAL TEACHING – What percent of your time/effort is spent in teaching Physiology?\_\_\_\_\_

Describe in the space provided your teaching of <u>physiology</u> including course descriptions (content, format); supervision of predoctoral and post-doctoral students; special contributions (films, textbooks, etc.).

# 4. **INTEREST IN THE SOCIETY** – List any APS Meetings attended by date and check the appropriate box for any papers.

SPRING (FASEB)		FALL (APS)	FALL (APS)			
Date	Presented	Coauthor	Date	Presented	Coauthor	

List other scientific societies of which candidate is a member:

In the space provided state your interest in wanting to join the Society:

- 5. SPECIAL CONSIDERATION Include any other contributions (Administrative, university, national service, awards and honors) that may be important to physiology.
- 6. DESCRIBE YOUR RESEARCH What percent of your time/effort is spent in research?\_\_\_\_\_

Describe the fundamental physiologic questions in your research and how you have answered these questions. Limit the paragraph to the space provided.

- 7. <u>BIBLIOGRAPHY</u> Attach a list of your publications under the following categories:
  - 1. Complete physiological papers, published or accepted for publication.
  - 2. Physiological abstracts (limit to ½ page).
  - 3. Other papers not primarily physiological (limit to ½ page).

The entire bibliography should not exceed 2 pages. Give complete titles and journal references with inclusive pagination. Use the bibliographic form found in the Society's journals. List authors in the order in which they appear in the publication.

DO NOT INCLUDE A CURRICULUM VITAE

Editor: Orr E. Reynolds, Education Office, APS Associate Editors: Edward M. Eisenstein, Dept. Biophys., Michigan State Univ. Robert E. Fellows. Dept. Physiol. & Biophys., Univ. of Iowa Mary Forsling, Middlesex Hosp. Med. Sch., London, U.K. Ann E. Kammer, Div. Biol., Kansas State Univ. Charles S. Tidball, Dept. Physiol., George Washington Univ. Med. Ctr. Executive Editor: M.C. Shelesnyak, A.P.S.

#### SCIENCE EDUCATION: AN EXPERIMENT IN FACILITATING THE LEARNING OF NEUROPHYSIOLOGY

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#### INTRODUCTION

When I began teaching six years ago, I adopted a format familiar to most professors and students. My purpose was to provide advanced undergraduate and graduate students with a reasonable breadth and depth of understanding of what neurobiology could be about, so that they would be prepared for further training in the field. As the instructor, and presumably the most experienced and knowledgeable, I assumed complete responsibility for planning the course. I developed a syllabus, composed lectures, wrote examinations, constructed laboratory exercises, and specified requirements.

The course acquired a reputation among students and faculty of being good, but requiring a lot of hard work. Some students flourished under the challenge I presented, but many floundered. As a result, enrollment dropped dramatically in subsequent years from 120 to 60 and then to 40 students. The class size decreased further as each semester proceeded because students who could not keep up with the work dropped out. The drop-out rate ran 30-40% most years.

I learned a tremendous amount by preparing for the lectures and designing new laboratory exercises. My teaching assistants shared my enthusiasm, supported the standards I set, and also learned a considerable amount from their association with the course.

With each year my view of teaching changed subtly. I gradually attempted to cover less material in lecture, and to give the students more time to do fewer laboratory exercises. I took more time to answer student questions, to ask questions of the students, and to request their participation in raising questions in lecture. I began to believe that the most important skill the students should obtain from the course was the ability to formulate good questions, questions which would provoke them to examine the subject in more depth. I found that I did not enjoy the job of requiring students to do a variety of tasks which I had selected, even though I truly thought them important and worthwhile. I derived little satisfaction from the antagonism that this engendered in students, and did not look forward to the anxiety such a test of power and wisdom produced in me.

I speculated that perhaps an atmosphere in which the students could 1) call upon their own diverse, previous experience and curiosity, '2) explore new topics in a manner best suited to them individually, 3) avoid direct competition for a grade, and 4) actively participate in deciding what they wanted to do as a class and individually, would be more conducive to significant learning. It might also expand the options available for exploration and study, and place the responsibility for learning on the students themselves. I saw myself as a coordinator/facilitator, helping all the students to achieve their individual goals, and as one of several sources of feedback for the student's activities.

Reflecting on my own approach to learning new things, and the generally positive response of the students to my attempts to have them raise questions, I began to feel more strongly that opportunities for student participation in their own learning should be maximized. I began to feel confident that the students could and would accept the responsibility implied. I was further encouraged to attempt something new by the writings of Carl Rogers on "student-centered" learning (1-4) and by several graduate students with whom I shared the evolution of my thoughts.

In the spring of 1979 I offered a course in neurophysiology which was conducted in a manner quite different from the way I had previously offered it, and probably quite different from most science courses offered at the University. The following reflections document what happened during the semester, and may offer insight and encouragement to others interested in the education of scientists.

#### ORGANIZATION AND CONDUCT OF COURSE

#### A. Beginning

I came to the class the first day prepared to follow one of two options. In one case the course would follow a syllabus, schedule, and tasks which I had outlined. The other option called for the students themselves to determine the syllabus and how the class would be conducted. As the students entered they picked up a memo which read as follows:

Memo to: Students Enrolled in Neurophysiology

From: Herbert Levitan

My principal goal in this course is to create the conditions whereby you have the freedom to pursue a study of neurophysiology in a manner which best suits you.

I do not consider you to be empty receptacles into which I must attempt to pour a collection of facts which I find interesting. Rather I ask you to actively participate in deciding what you wish to learn and how you want to learn it, based upon your previous experience and interests.

I hope that in this process you will become capable of asking fundamental questions about the subject, and develop the confidence and independence to answer them using your own resources and initiative. I also hope, and fully expect, that I too will learn about areas of neurophysiology which previously I had no motivation to explore.

If some of you are uneasy about participating in a course structured in this way please share your feelings with us. I myself am apprehensive about how the course will evolve and turn out but I feel the risk is worth taking.

The discussion which followed was recorded on magnetic tape, as were almost all subsequent class discussions. I can thus ascribe comments to students and myself with a fair degree of accuracy. Copies of these recordings were also made available to the students. At my invitation many students expressed their interests and what it was they wanted to study or learn about in greater detail. At one point a student commented, "I really like the way you put this memo. I am used to a teacher giving a syllabus or something very structured the first day of class. This was more open and I like the idea." I appreciated her directness and told her so.

Acknowledging the diversity of interests which had been expressed I noted that in my experience the instructor tends to ignore the diversity of interests and background of the students in the class and tries to fit everybody into his or her mold. On reflection it did not seem right to me that I should impose upon the students my background and inclinations. I thought that the course might be more dynamc and interesting (for me) if I gave greater consideration to where the students were coming from and where they wanted to go. Such an approach involved a significant risk from my perspective because I did not know if it would work.

After additional students expressed their interests and aspirations, I offered to outline what I thought was a spectrum of the possible ways to proceed. We could then vote on the style which best suited our collective purposes. At one end of the spectrum an instructor would provide an outline, a reading list, establish tasks (e.g. exams and papers), set due dates and conduct evaluations, without any explanation or justification to the students. In the next category an instructor would do these same things but justify them, by explaining the logic of the organization and the reason for the tasks. While the students could not alter the course plan, they would have some appreciation for the "method behind the madness." A third alternative provides an opportunity for student input. Such a course might begin by reflecting the interests of the instructor. Subsequently, but presumably early in the course, the emphasis would change so as to reflect more the curiosity of the students and the questions raised by them as a result of what was initiated by the instructor. The students could also provide more input as to the tasks to be performed. They might for example help to write the exams, and decide what should be done in the laboratory. At the other end of the spectrum the students would participate from the start in deciding what should be covered in the course. They would help make up a course outline, which would be modifiable with time to reflect the increased sophistication and changing needs of the students. The students would decide with the instructor what tasks should be carried out, whether there should be exams and/or whether other tasks would be encouraged (such as research a paper). These possibilities for conducting a course thus run the gamut from authoritarian to egalitarian. The class then shared their feelings about these possibilities, expressing varying degrees of support, reservations and modifications, responding to each other's ideas as much as to mine.

About midway through this first class I asked whether anyone felt disturbed by this lack of organization and if so to share their feelings with us. Some structure was thought to be important by several students because they had many other commitments, classes and labs to schedule. In response a student offered the opinion that the usual environment in which students are obliged to block out specific times for doing certain tasks did not provide a good learning environment. One should not be pressured into meeting deadlines set by others, he felt, but be free to go to the library to pursue topics of interest as they arose.

During this discussion I mentioned that I felt that listening to lectures was a very inefficient way to learn. One student responded that she did not learn during lectures, but they provided her with material to think about a later time. Another student said he wanted me to present material in lecture or seminar format with discussion possible because he felt that I knew more about neurophysiology than he did.

When asked by another in the class why he felt that way, the student responded that I had been at it for awhile. The individual who challenged initially was not satisfied with that reply, but as he hesitated a moment to retort the student said to me, "OK, let me give a lecture." I said that it would be more appropriate to ask the students. The response of the class surprised me by its good sense. One said: "I don't know; how prepared are you?" "Biophysics," he said, "I could come up with something." "Make it interesting and you'd be more than welcome," was a response. At the conclusion of this exchange, I suggested that students were welcome to prepare a lecture for the class. The student's "credentials" really wouldn't matter. A willingness to listen, expressed by the class, would give the potential lecturer the confidence to do a fine job, and both the lecturer and the class might gain a lot. It is significant I think, and appreciated only in retrospect, that the exchange occurred only partly in jest, which allowed this student to propose at a later date that he be permitted to give a lecture.

Towards the end of the first class meeting I asked: "Does anyone feel that this discussion is a waste of time?" "It's not for me at all," a student responded. "I was very intimidated... because I had very little experience about the subject matter... I just walked in really fearful (because of what she had heard about the course previously) and I feel a lot better about the whole thing... It appears that there is going to be a substantial amount of student involvement and it won't be all you telling us what your expect." Another student said: "The more time you do spend like this the more open minds will become in class... so they can let it all hang out and learn." At this time no one expressed any reservations about the time we had been spending on organization. I reminded them of the other important decisions which we had yet to make and which would take some more of our time, but I thought that this was preferable to having me make all the decisions and imposing the procedure on them. At the end of the course a student wrote that she felt "...too much time was spent 'making decisions,' thus wasting class time. I think that we could have been presented with a list of decisions to consider, together with a default decision in each case. The class time spent on this, then, could be restricted, after a thinking period, and any decision not made in allotted time would go to the default. I do think, though, that the idea of the class making decisions is a good and innovative idea. At first everyone seemed baffled, but I noticed that almost everyone took a much greater interest and responsibility for his/her part in the course than normally exists."

I was very encouraged by the number of students who participated at the first class meeting, and the frankness of their contributions. A majority of the students present seemed to have expressed their views, interests, and reservations in the discussion, and I sensed from what had been said that the students were at this point cautiously optimistic about what might happen.

At the beginning of the second meeting, I provided the students with an accounting of who their classmates were, and asked for their response. This information came from cards I had asked the students to fill out at our first meeting. There were 7 juniors, 21 seniors, and 15 graduate students, representing areas such as Zoology/Biology (21), Entomology (1), Psychology (4), Physical Therapy/Education (3), Mathematics (2), Engineering (5), Physics (1), Biochemistry/Chemistry (5), and Independent Studies (1). The question of class composition was raised by an undergraduate after our first meeting. He apparently felt intimidated by the nature of the comments and contributions made by his fellow students and was concerned that he might be at a disadvantage if he had to compete with mostly graduate students. In discussing the diversity represented by the list it became apparent that no one group or individual had a clear advantage over the others. Someone said "so many grads and postgrads in the class... would be able to add that much more to the class." Another said she, as an undergraduate, felt the competition with graduate students would encourage her to work harder to make up for the maturity they might have.

I hoped that by airing the students' feelings they would realize that they each had something to offer. Our organization of the tasks to be done could lead to cooperative instead of competitive feelings and this might remove some of their anxiety. I said that the only imposition we had on what we do in class was the obligation to submit a grade at the end of the semester, but I believed we had a lot of flexibility in deciding how to arrive at that grade. Decisions about what tasks the students could perform and what criteria should be used for evaluating these tasks could be made as we went along. I expressed my inclination that in the end each of them would decide themselves what their own grade for the course would be.

At this second meeting I also handed out a list of the topics which the students had contributed at our previous meeting. The list (Table 1) represented their interests and obviously reflected the diversity in the type and extent of their previous experience. I asked them to examine the topics with the objective of organizing our interests into a coherent, logical syllabus. To aid in this process I suggested they consider the following questions: 1) what it is we wish to know about each topic (in as much detail as our current experience allows), and 2) what background material we need to have in order to appreciate fully the information we gather on the topic? Table 1. Topics of Interest to Students Beginning Course

Cerebral/higher intellectual functions such as memory, learning, consciousness

Physiologica basis for mental process (Psychophysiology) Behavior

Cellular basis of behavior

The genetic basis of neuronal function and behavior

Developmental neurobiology - development of neuronal form and function

Neuroanatomy - Human and comparative

Sensory Physiology - How environment is sensed and system responds

Vision

Pain and its control

Sensory - motor function: basis of normal motion, pathological movements

Nervous control of muscle activity

General interest in how nerves and nervous systems work: Properties of nerve cells and their interconnections

Comparative neurophysiology

Cellular neruophysiology

How nerves control other body functions

Computer simulation of neuronal function

Neuropharmacology - How drugs affect nerves and nervous interactions

Experimental techniques used in study of nervous system function

In viewing the list the students recognized that several of the topics they had suggested fell together naturally and could be arouped. One student felt that the content of the course should be dictated more by the strengths of the instructor than the diverse interests of the students. Another thought that selecting chapters from the text book would be a good way to begin. I told them that I would provide a listing of several texts, chapters and original articles which would be available in the library. The students could sample these references and determine for themselves which spoke to them best. As a consequence of the discussion which followed it was decided that I should present some background or "core" material on the workings of nerve cells and their interactions, since many expressed the desire to have an overview, and this seemed to most of the class to be basic to all their other interests. Then we would review where we had been and discuss what to do next.

#### B. Students' Comments on Beginning of Course

The student's written comments concerning the beginning of the course confirmed the attitude of cautious optimism and uncertainty which I sensed during early class discussions. They wrote in diaries: "It sounds great that we will be deciding our own syllabus," and they looked forward to a class in which it might be possible to begin with questions based on phenomena they were already aware of. But they were also "kind of scared as to what will happen in the end... because... we're faced with a wide variety of topics to choose from and the responsibility of prudent decision."

Having the students decide the format of the course was "an interesting approach for mature students (but) how will immature students fare?," another wrote, adding that "it really (is) uncomfortable to have to decide what we want to get out of the course... (and) the issues of grading." Many felt uneasy at the

beginning because they were "used to the professor dictating the grounds of the course. That way I knew what I would be up against." The key to resolving these fears seemed to be expressed by a student after he talked at length with the teaching assistant. He wrote, "I've decided that for me this course will be successful because of the mutual trust betwen (the instructors) and the students."

#### C. The Lecture Process

Before lecturing on the "core" material I wanted the students to realize that they would be getting primarily my view of and my approach to the subject. I also wanted to have their input and utilize their questions to motivate the class. I began by trying to think about how they might approach the nervous system, what questions they might have on first viewing the system, Given these observations I asked what questions occurred to them and listed their responses on the board. These questions were then organized into a minisyllabus, and I provided a list of relevant references consisting of textbooks, review articles and original papers.

Based upon our readings or other previous experiences, the students or I would then make suggestions about how we might design experiments to get answers to these questions. The limitations of various experimental designs were discussed in the process. The results of an experiment using these suggested experimental techniques would then be provided. Based on these observations other questions would be raised and the procedure repeated.

In sum, the lecture periods consisted of (1) raising questions based upon the current state of knowledge of the students, (2) considering what information they would have to have in order to answer the questions raised, (3) suggesting experimental procedures which might provide the required information, and (4) considering new questions which would arise as a result of the information gathered. Each such question session served as a branch point at which a choice had to be made concerning which direction to take. In this sense the course syllabus was not predetermined but flexible.

Reviewing the topics which were discussed by the class it appears that most of the items which the students expressed initial interest in were considered in some way. Approximately the first two-thirds of the "lecture" time was devoted to discussing the properties of nerve cells and their interconnections (excitability and voltage dependent membrane conductances, nerve conduction, synthesis, storage and release of neurotransmitters, and the initiation of changes in postsynaptic cells). This naturally involved discussion of aspects of cellular and comparative neurophysiology, neuropharmacology, nervous control of muscle activity, the cellular basis of behavior and experimental techniques. Photoreception and the mammalian visual system, and current theories of the nature of memory were also discussed. The students considered aspects of human and comparative neuroanatomy, and carried out a computer simulation of excitability independent of the formally scheduled lecture and laboratory time. Individual students explored a variety of additional subjects as indicated by the annotated bibliographies and papers they included in their portfolios at the end of the semester.

The course was thus much more interesting and challenging for me than would have been the case had I alone determined its direction. As one student observed, "This class required alertness, thinking and application of already known phenomena, something which are not required in most other classes. The students seemed actively engaged in the lecture, developing the points together; or dispersing the point with opposing views, but at least there was interaction between minds."

## D. Organization of Laboratory

A laboratory was officially a part of the course, i.e., a time segment of three hours per week was designated for laboratory experience. I therefore asked the class to consider what purpose a laboratory should serve for the student. In the course of the discussion of this topic, the students recalled several positive and negative aspects from their previous experiences with laboratory courses. As advanced science students they had considerable experience in several university departments.

Several students were concerned about the amount of time it would take to write up laboratory reports. One student thought that he might be lazy when it came to writing lab reports and he would appreciate being obliged to write them. He felt a great weakness of students was their inability to put together a creative report. In response another student said that she was often able to involve herself in a project a lot more enthusiastically if it came from her wanting to do it instead of having to do it. Another related the experience of his wife who teaches piano. She discovered that if she admonished her students never to practice more than five minutes a day they invariably practiced 30 minutes. Eleven or twelve students wished to commit themselves to writing reports for each laboratory.

Students were also concerned that they would have nothing to write about if no data were collected from an experiment they carried out. I expressed the philosophy that one learns by one's mistakes, and that students should come into the laboratory with expectations of what they hoped to observe. If things turned out differently they would have a basis for discovering someting new. The collection of data need not be critical. Students who did not collect data could obtain relevant numbers from the instructor or the literature. Alternatively, students who were successful in gathering data could make it available to others. A great deal could be gained by analyzing, interpreting and discussing the data irrespective of its source.

As a result of extended discussion it appeared that the general consensus of the class was that the purpose of a laboratory should be:

- 1. Provide another activity (besides listening, reading, or watching) whereby the student can acquire a firmer understanding and appreciation of basic principles and current paradigms.
- 2. Provide an opportunity for students to appreciate the experimental observations upon which the currently accepted principles, paradigms and dogma are based, i.e., the experimental basis for the current dogma.
- 3. Gain an appreciation for the limitations which apply to the generally accepted paradigms.
- 4. Gain technical experience.
- Gain an appreciation for the kinds of questions one can reasonably ask and how one might proceed to answer them experimentally.
- 6. Have an opportunity to test or evaluate their understanding of the material.

To accomplish these objectives, most of the students felt that demonstrations by the instructor should be minimized and as many students as possible should have hands-on experience with the various tasks required to carry out the experiments. By repeating some aspects of "key" experiments, an appreciation for the experimental basis of the current dogma could be obtained. When asked whether they preferred experiments which illustrated "key" non-trivial points or trivial, easily accepted points they were inclined towards the former. An appreciation of the limitations of the dogma could be gained by becoming aware of the assumptions made and the experimental conditions. Analyzing data, interpreting results, and comparing their conclusions with others might aid this process.

A varied technical experience could be gained by performing such tasks as dissection, checkout and manipulation of instruments, and recording data. I asked the students whether they thought the experiments should utilize current, state of the art technology and instrumentation or be of historical interest with appropriate instrumentation, and whether the experiments should provide a conceptual and technical challenge to execute or be trivial to execute. More specifically they were asked whether they preferred to attempt experiments which:

- a. were fail safe, guaranteed successful,
- b. had a high probability of success, i.e., more than 75% rewarded on first attempt,
- had a moderate probability of success, i.e., 25% would be successful the first time, 50% the second and 75% the third time,
- had a low probability of success, i.e., 10% the first time, 25% the second, and 30% the third,
- e. were "impossible," wherein no success was probable the first, second or third times, even for the very experienced, but after a dozen experiments the success rate would apprdach 50-60%?

Most students appeared to prefer category (c) although they felt that category (e) probably approached more closely the conditions of original research.

In order to gain an appreciation for the capabilities of the experimental system, the students chose to make use of laboratory instruction sheets I had previously prepared. They apparently felt more comfortable beginning with instructions in a cookbook manner. It was understood, however, that they were always free to explore other questions, and design other experiments. What was recorded and how it was recorded by the participants was left to the students to decide. I recommended that the decision as to what and what not to record be an active one rather than one made by default. I also suggested that the students organize their groups such that one individual accepted responsibility for recording what was happening. This record could subsequently be distributed over his or her signature to other participants. Other group members could indicate their role in the experiment as well (e.g., dissector, instrumentation technician, etc.) to make the record complete.

To evaluate their efforts in the laboratory and test their understanding of the material interested students had the option of writing a report of their activities and seeking feedback from the instructor and their peers. A handout on the preparation of laboratory reports which I had previously prepared was made available for those who wished guidance in deciding what should be included. Those who submitted reports were expected to critique the reports of at least two others and I suggested they address particularly, such questions as:

- a. Does the introduction correctly and clearly state the principal objectives of the experiment?
- b. Is the description of methods complete enough to allow an understanding of what was done and how?
- c. Are the observations clearly described? Are the analyses of results clear?
- d. Is the interpretation of data logical? Is a comparison made with relevent literature? Are differences considered and limitations of dogma recognized?

e. Are the references to published material complete and correct?

No grades were to be assigned. It was left to the authors of the reports to use the critiques as they wished to enhance their understanding of the material and improve their ability to communicate that understanding to others.

#### E. Laboratory: Student Comments

The students also expressed their satisfaction and dissatisfaction with the organization and conduct of the laboratory by writing notes in their diaries or in their course evaluations. Their comments ranged from feeling "that the lab could have used more structure as well as a more rigid requirement" to finding "the atmosphere in lab very conducive to learning...(permitting) good interaction to occur between our lab partners." Some students made suggestions for improving the laboratory experience. "Demonstrations - followed by 'hands-on' labs - would have been (enormously) helpful," wrote one. Another found it difficult to find adequate time to satisfy his curiosity about how the equipment worked and suggested that students be allowed to help set up the apparatus. In this time students could "ask basic, fundamental, elementary questions about the apparatus in the absence of pressure to perform an experiment," and they might also help to reduce the instructor's work load. He added that setting up might also give the students "practice for doing it in the future in some other setting, like grad school or on a job." Another student came "home from labs saying that this is really what science is all about, ... what it is (like) to be a scientific researcher." The "loose structure" allowed the students the freedom to linger over and discuss phenomena they found interesting and to "try new ways of investigating that phenomena." This would not have been possible, he thought, if one had specific deadlines to meet. The possibility of writing laboratory reports evoked a variety of responses. One student "realized" the lab reports should be long and should cover material in great depth. She decided that she would not gain much from such a time consuming task and so did not submit any reports. Another student regretted not handing in for evaluation any information gathered during the lab. He found the experience beneficial, however, because "it helped to point out the areas that I need to concentrate upon if I am to continue any type of research." For one student who had never before been required to write "formal lab reports," with an introduction, methods and results, the task was very difficult. He found that writing all the reports proved "to be a very useful experience, and one that will obviously be useful for me in the future since I plan on going to graduate school. Looking over my reports I was surprised to see how much my lab reports improved. My first lab report had no comparisons with the current literature. My last two are well supported by the current literature."

#### F. Neuroanatomy Mini-Course

Many students expressed an interest in neuroanatomy (human and comparative). Neuroanatomy lectures without concomitant discussions of function, were not of interest to me and I expressed the opinion that learning the names of brain structures could be accomplished by referring to books without the help of an instructor. I recalled the great impression my first view of a human brain had on me, however, and I told the class that I would try to obtain a human brain for interested students to examine. Through the generosity of the Maryland Anatomy Board, location at the University of Maryland Medical School in Baltimore, I. was able to obtain two preserved human brains. One of the students in the class volunteered to pick them up.

Upon further reflection, I decided that if several students were so inclined they could dissect the brains. More would be gained by manipulating the brains than by simply looking at the surface features and I told the class that I would make the brains available for dissection if those interested would draft a plan of study so that maximum use was made of an unusual opportunity. More than half the class signed a sheet indicating various degrees of interest in participating in this activity. Some wanted to dissect, others wanted to watch a dissection, and still others just wanted to talk about neuroanatomy, and look at already prepared sections, slides or pictures. Two students in the class had access to already sectioned brains and volunteered to made these available to the interested group.

The interested students held several planning sessions outside of class and a protocol was developed whereby a student with previous experience in neuroanatomy would collate some relevant material and lecture to those interested. I was asked to find a room which they could use on an afternoon which was convenient for most of them, and I made available my personal copies of books on neuroanatomy and brain dissection.

As these sessions proceeded, the number of students participating decreased to about 1/5 the class. The assistance provided by the "Anatomy Instructor" at these sessions was greatly appreciated by the others (as indicated by their response to a survey she had the students fill out). Although the group made good use of the sections which were brought in by the "instructor," for some unaccountable reason, the students never actually dissected the brains I made available. A few of those who dropped out of this study group commented to me that they stopped participating when they realized that it made little sense to remember the names of structures without also studying their function. They were not able or willing to devote the extra time needed to learn the associated function.

#### G. Computer Simulation

At the beginning of the course, a couple of students expressed an interest in learning about models of the nervous system and nerve function. It was appreciated that they would have to understand the basic principles of nerve function before they could model it. When that time arrived, I made available a computer program which simulated nerve function and gave them instructions on how to use it at the Computer Science Center. Since many of the students had not had previous computer experience, I encouraged them to try to follow the instructions which were designed with naive students in mind. In previous years, only a few students made use of this additional, alternative way to understand the functioning of a nerve. The pressure of other obligations had apparently inhibited all but the experienced from devoting the time necessary to explore an entirely new medium of expression, interaction and analysis. This year, however, the students felt freer to experiment, and many novices accepted the challenge. Some were frustrated and gave up early, but others persisted and sought help at the Computer Center or from more knowledgeable friends until they succeeded on their own. Their comments expressed their frustration and satisfaction, and the impetus this experience provided for them to further explore this new medium.

#### H. Examinations

Many of the students assumed we would have exams but were uncertain of how it would come about given the way the course was evolving. In preparation for discussing the matter of exams I asked the students to draw upon their vast experience and consider two questions: (1) whether they would derive any benefit from preparing for an exam, and (2) whether they would derive any benefit from taking an exam.

Studying for an exam, several students suggested, provided an opportunity for organizing a broad body of material, more so than if one were reviewing material to write a paper, for example. It also allows one to get feedback of one's understanding of that material. Being obliged to organize a body of material gives one the opportunity to observe relationships between subjects that might have been missed when they were previously covered sequentially. On the other hand it was the experience of another student that preparing for exams most often had the aspect of trying to figure out what the instructor wanted and guessing what might be asked. Were it not for this game it could be a valuable experience. "Having to second guess the instructor usually means that you don't get a chance to study what you are really interested in."

One of the values of taking exams is the opportunity it offers for feedback on whether your organization of the material and understanding of it is logical and accurate, suggested a student. Another recalled the value of questions written in such a way as to correlate previously isolated or unrelated material. The student then has an opportunity to learn something new while taking an exam. This can happen when the questions allow a new synthesis or a discovery that principles applicable to one situation are in fact applicable to others not previously considered.

A student who appreciated the value of this said she "would rather not find this out during an exam, but rather on a less formal basis." The pressure to perform in the confines of an hour also made the experience of taking exams unpleasant for some. But one student felt that the anxiety produced by knowing one has an hour to perform was not necessarily bad, and that she often felt relieved to know that the exam would be completed within a finite time and very relieved when it was all over. One way to alleviate the tension often accompanying exams, a student suggested, was to allow take-home exams. Another thought that the method of grading exams was also crucial to how one felt about the exam process.

We then considered how the exams should be created (i.e. by whom); how they should be taken (in class, at home, by everyone or not at all); how they should be evaluated (what criteria should be used, how should the various aspects be weighted) and by whom.

Someone suggested that the students themselves could write questions on the body of material covered based on things they thought they would like to know and should know. To avoid missing points that others find important, the comments and criticisms of other students could be invited. "Making up clear and unambiguous questions is a fine art which comes with long years of experience," thought a member of the class. Questions made up by students therefore are typically very unclear and ambiguous, in this student's experience, and he would prefer to have the instructors rewrite questions submitted by the class. This procedure avoided an aspect of learning and taking exams which I thought should perhaps also be evaluated. By writing an exam the students would be inviting feedback on their ability to communicate clearly.

The students were concerned about their ability to make up questions which would challenge the rest of the class and which they could answer correctly. Being able to support clear, logical statements was more desirable, I thought, than "correct" answers. They were concerned about being too narrow in their selection of questions and missing many aspects of the material. I thought it was important to develop the skill to identify the key points in a body of knowledge, rather than having to depend on others. They were concerned about the time it would take to accomplish all of this. Some students preferred to be given questions to answer which had all these desirable characteristics, and others wanted to limit in some way the time invested in the exam process.

One student, responding to another's desire to have a numerical grade of his effort on an exam, said that the options being proposed offered "a golden opportunity to break out of that old mold. I am so familiar with those traditional tests that given the choice I am not willing to submit myself to it. You don't get the opportunity very often to get out of that. We are so ingrained (in the old mold) that it is like we are sitting here wanting to submit to anything they'll do to us."

Those students interested in attempting to answer questions posed by others could choose from the pool available. Upon completing their answers they could refer to those provided. If desired, the authors and respondents could confer with each other and/or with additional source material in order to enhance their understanding and resolve any differences.

It was left to the individual students to decide whether or not to participate in any of this activity.

Any material generated as a result of participating in the examination process should be included in the Portfolio presented by the students at the conclusion of the course, and used to support their final course grade.

#### I. Examinations: Students' Comments

Through entries in their diaries and in their course evaluations the students expressed their thoughts on the examination process they helped design. The following statements are extracted from these documents.

One student related that he had previously taken a graduate level course in neurophysiology at another university and "knew he had a good knowledge" of the material. But he "learned a lot more making up exams." He found it difficult and very time consuming to make up questions in the multiple choice format which he had chosen, and finally did not turn in for evaluation the first exam he made up "because he didn't think his questions were 'good enough.'

Another student didn't hand in an exam because he felt that writing questions for himself would not be an effective use of his time. He decided after reading over the material covered so far in the course that he understood it well and that he would test himself by trying to answer exam questions which other students submitted or those which I had made up in previous years.

Another found that "... creating exams were very benefical because I learned that posing unambiguous questions is very often difficult." He found himself "interested in asking questions I wanted to answer because they were valuable to me."

Most agreed that making up an exam was more difficult than taking one. "The exams were extremely challenging," said one student, "and I am proud of how mine turned out. They provided an excellent way for me to synthesize and condense the course material. The most rewarding experiences when writing the exams were when I wrote a question that I could not answer, and had to keep digging into the material until I found the answer. I never dropped a question because it was too difficult!"

#### J. Student Lecture

About halfway through the semester one of the students asked if he could give a lecture to the class. (I had completely forgotten that on the first day of class this same student had a somewhat tongue-in-cheek exchange with the class about students giving lectures.) He wanted to present in greater detail the thermodynamic basis of some material we had previously covered in class. Admitting skepticism, to myself at least, I suggested he write a proposal outlining what he wanted to do and how, which he should submit to the class for their response. With his outline he included a questionnaire which addressed the conditions under which the class might want to hear what he had to say. The class was overwhelmingly receptive to this student's proposal! An uncertainty arose only because half the class wanted to hear the lecture during class time and a half wanted to schedule it another time. The only feasible way to resolve this conflict was to hold both the regular class and the "guest" lecture at the same time in different rooms, allowing students to choose between the two.

The "guest" lecturer handed out the details of what he had to say several days before the meeting so that everyone would have access to his efforts. About 10 students attended the lecture/discussion he conducted, and their responses to his "debriefing" questionnaire indicated a very favorable reaction to his efforts and to the idea of "allowing," or encouraging students to develop and deliver lectures. The student was obviously pleased with his effort but said, interestingly enough, that once he had prepared the handout detailing what he had to offer, it did not matter to him very much whether a convenient meeting time could be arranged. He had already gotten out of the experience most of what he wanted.

#### EVALUATION OF COURSE

#### A. Students' Self-evaluation

The question of evaluation kept arising as we spoke of the various tasks and activities the students could carry out in the process of learning what it was they wanted to learn. The students repeatedly asked how I was going to evaluate them, a question which reflected their past experience in courses in which their ultimate objective was to please the instructor. While granting that an instructor's critique and evaluation of students' work are of great importance, I was strongly inclined to have the students themselves play a major role in evaluating themselves and each other. I wanted them to have the experience of attempting a self-evaluation on the basis of feedback received on documents they had written and submitted. I wanted them to gain confidence in their ability to realistically and fairly evaluate themselves and thereby arrive at a letter grade which could be submitted to the University. The character of the evaluation process evolved as the course went on.

All the students wishing to have a grade submitted to the University in recognition of their participation in a neurophysiology course were required to submit a portfolio containing all written material which reflected the work they had done during the semester. In addition the students were asked to submit a diary or journal containing their insights, perception of progress and their reflections on the conduct of the course, as well as a justification of the grade they wanted submitted. I reminded them that I reserved the right, and indeed felt the obligation, to give them feedback on the grade they assigned themselves. I made clear, however, that I would respect their final decision on the grade they wished to have submitted.

The process of self-evaluation was new for most of the students, and difficult for many of them. A majority reflected very seriously on their self-evaluations, and submitted honest, sometimes agonized, commentaries on the conduct of the course

and their response to the responsibilities and burdens it placed on them. Particularly revealing were statements made in their diaries, statements which reflected their daily activities, problems, successes, anxieties, insecurities and triumphs. I quote from some of these below.

"I suppose I could compare my progress to the others in the class but I got the idea that we were to feel a mood of cooperation not competition, so that is not a valid way to gauge my progress. So I guess that just leaves me to fend for myself, as it were (I'm beginning to think that this was the idea all along...). Sitting through three days of a symposium (at the National Institutes of Health) whose list of speakers read like the Who's Who of neurobiology and really being able to understand the ideas presented, surprised me. To be honest, I did not realize I understood the subject matter that well... Realizing where I started with the course work and where I am now, I deserve an A.

"Based on the amount of time I spent in (class) compared to the amount of time I could have spent and the number of concepts I could have learned I give myself the grade of C for the course. I did not think a higher grade was justified simply because I did not make a formal attempt at synthesis of a topic of interest (term paper, exam, etc.). Also a lower grade would not reflect the amount of time I placed in the course and my satisfaction with what I have learned."

"Evaluating myself is difficult but I will try and be objective. I feel I've come a long way since the start of the course. Instead of just learning facts I learned how to ask questions and approach a problem... But more importantly (I learned) how to discover more on my own. I believe my effort in this course is worth a B."

And finally, "I need to show the medical schools that I am capable of doing hard science, and am not afraid of doing so. I am hoping that the fact that I have taken this course will look good on my record. Perhaps I am being too honest with this admission.

I fear that I spent too much time synthesizing material for my understanding in the early part of the course and not enough time trying to come up with a written product. This question of quantity of written work produced on a personal scale (and not as compared to other students) is the main reason why I have given myself a B."

The distribution of grades submitted for the course was: 33% A, 45% B, 20% C, 2% D.

I wish more of the students had kept more complete diaries for their own, as well as my benefit. One individual wrote a paragraph summarizing what was done each time the class met either in lecture or lab and what impact it had on him. Most wrote less frequently, but from my reading of the comments they are honest statements, and reveal a great deal about the positive and negative aspects of the course, and the learning process. Perhaps the most significant aspect of the students' comments was their focus on the students themselves, what they did or did not do, how they grew, what they learned, etc. I detected relatively little commentary about the personality, style, or knowledge of the instructor. That is, the students appeared to place the responsibility for the learning process clearly on themselves. Some of their comments follow.

#### B. Students' Evaluation of Course

"What was done this semester in (class) was a remarkable attempt to undermine some standard education procedure. During the first few weeks, the class as a whole was inundated with questions which are normally decided by the professor. The class seemed (as a whole) quite impatient. (One could almost hear the words "we came to learn [Neurophysiology], so why can't we get started)." Some students voiced an opinion that a freedom to choose was great and that it was a much better idea than a structured situation. Of course other students said exactly the opposite. Those who felt a liberal atmosphere would be conducive to greater depths of understanding were surprised to find how little they could work when nothing was actually "due." (This is not all that surprising when considering that for more than 15 years students are conditioned to study for in-class exams and turn in mandatory assignments.) Those opting for more structure, realized, I think, that with a little self discipline one could learn a great deal."

"It was planned in the beginning of the semester that Dr. Levitan (as the prime holder of wisdom in the classroom) would lecture on a set of "core topics" without which other interesting areas of neruophysiology could not effectively be attacked. After this introduction, students were to branch off into whatever they chose to do. Clearly the course unfolded a little differently. Part of this change of plans was occasioned by the nature of the discussion in class. Even though topics to be discussed were outlined ahead of time, each was approached with a sense of discovery. Data was presented at times and conclusions asked for, and at other times hypotheses (from the class and/or Dr. Levitan), listed and experiments asked for to differentiate between them. The class as a whole, it seemed to me enjoyed this encounter session with science. Enthusiasm in the subject matter was at times quite high (e.g. on several occasions there was argument among students on the interpretation of some data - clearly something quite different from what one usually finds in a science course...). Overall I think a class such as the one we experienced this semester is suitable to a group of students who are willing to interact in the classroom, do a reasonable amount of background reading for the discussion, and who are interested in the subject matter being discussed. Regardless of how one classifies oneself with respect to this group of students, an experience like this semester will help formulate one's opinion about other educational methods, taken usually without question."

"The method of democratically deciding on what areas we would investigate in class was laborious at times, though the results seemed to please everyone... I much prefer only having to worry about my own standards for judging my achievement and understanding of the material. Too often exams force a student to learn the material in the teacher's way, and this detracts from the excitement one experiences in learning new material."

"This course has indeed been a unique experience. It makes one think much more than other courses at this university. But for someone to come into this course, who has not done much independent work, it is quite a shock. It is hard to organize and be productive without someone constantly telling one what to do if one's not used to it... I think this could be a problem for some people..."

"...my feelings are mixed; almost confused. On the other hand, the respect offered the student cannot help but to nurture our maturity. Consequently those tasks that are promoted by maturity and self-esteem will be made manifest. These tasks include independent research and creativity. On the other hand, more regular and more demanding tasks, such as required examination, aides the accumulation of fact if not its assimilation. For myself a compromise was in order. The flexibility we found was certainly important. But what of new knowledge? Would I have read more thoroughly in our text had the threat of exam been there? Yes, unfortunately. In analogy to a Ph.D. qualifier one studies diligently for the exam and having passed it, lets the knowledge slip knowing that at one time all that knowledge was there, immediately callable, and hence will again be available with some work if needed. Nevertheless the experience was valuable in an intangible way. I don't think any future course will be quite the same."

"I think the new flexible format of the course is conceptually an excellent idea. However, I am the product of a system built around assignments, deadlines, and conventional examinations. Therefore, with this course graded by the flexible method and four other courses graded by the more conventional methods I tend to give less attention to this course than it merits due to lack of well-defined requirements."

"While I can appreciate the reasoning behind the course structure I am in disagreement with the method. I personally feel that democracy has no place in the classroom for an introductory course. A benevolent dictator (can more efficiently) teach a course covering a lot of new material. My reasoning is this: I primarily want an instructor to dump as much material on my head as possible per classroom hour. This allows me to go home and sift through this information, organize it and recognize what I don't understand. Also (and probably the main reason), it saves me a lot of time. The days you strictly lectured and answered questions were excellent and very enjoyable. The days we discussed how and what to do were, in one word, a drag."

"This whole course has been a stretching experience for me. Never before have I been responsible for so much material in one course, and never before have I not been spoon-fed the material by the professor. I can honestly say that neruophysiology was only a portion of what I learned. I also learned how to be responsible for keeping up with assignments, how to write exams, and the necessity for being well read in journals... I would like to extend my thanks and appreciation to Dr. Levitan, (the T.A.), and the entire class for making this course very rewarding for me."

The proportion of students completing the course was greater this semester than at any time in the previous six years. Only one student dropped the course, and he went out of his way to explain that his decision was based on extraneous circumstances.

#### C. Summary Evaluation

I strugged for some time with the feeling that "structuring" the course in the way I have described made me very vulnerable. The students might take advantage of *me*. They might do less than / thought they should and less than students in the past had been required to do. They might not take the initiative, accept responsibility, and show *me* that they could learn on their own. They might fall prey to the explicit pressures and requirements of other courses and not realize the great pleasure from learning something oneself. But I found that taking sole responsibility for the course content and requirements was an unrewarding burden. In the power struggle related to such an autocratic procedure, no one wins very much of consequence, and little learning of lasting importance takes place.

With practice one gets better at learning, at educating oneself. Some students who had been "trained" to educate themselves by parents of special education programs, recognized their advantage with respect to others in the class, and expressed it to me. They were grateful for the opportunity to exercise that option again at the University. They also reflected upon their stuttering start, their floundering and initial frustration until they learned how to learn.

Those in the class who had not previously had the opportunity to experience these symptoms exhibited and reported the tell-tale signs. The process takes time, proceeds faster in some than in others and should not really have an end point. But the beginning, the initial experience is often clearly delineated. Perhaps in the future some of the students will let me know that this course served as the beginning for them.

Heading the list of things I would do differently next time is improving my role as facilitator of the learning process. One way to accomplish this would be to organize and summarize more extensively and explicitly the contributions which the students have made during previous class discussions. This would serve to show the students that in fact much had been accomplished in what appeared to be rambling, apparently unfocused, questionraising discussions. Such periodic summaries would also help the class to focus on new questions and problems.

In sum, I feel the course was a step closer to the way I think it should be than it was previously. It was a step I very much enjoyed taking.

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#### AN APPROACH TO A PHYSIOLOGY COURSE FOR INDEPENDENT STUDY H. I. Modell

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The demand for effective materials designed for independent study settings is increasing. Eighty-four percent of the U.S. medical schools currently include "self-instruction" as part of their curricular options (1), and many post-graduate and continuing education efforts are directed toward self-learning. The types of materials available for us in these environments cover a wide spectrum from written documents (e.g. textbook, syllabus) to slide-tape, videotape, and computer assisted instructional material. In most cases, the common element in these modes of instruction is that information is presented with little opportunity for the student to be an active participant in the reinforcement of concepts. The purpose of this report is to present one approach to designing independent study materials which overcomes this limitation. A course (module) in normal Respriatory Physiology utilizing several types of media to present active learning experiences has been developed as part of the Self-Paced option of the University of Washington Medical School curriculum.

The module was designed with three key features in mind: 1) Resource material should accommodate a variety of learning styles; 2) a problem solving experience should be provided; and 3) a vehicle should be provided by which students can reinforce their learning by reasoning from basic facts to general concepts.

#### Primary Resource Material

Commercially available resources are used for primary instruction material (2,5,8,9). Resource material is drawn from several texts, but only one is recommended for a given subject area. The specific text chosen for a given subject area reflects the tutor's opinion as to which author provides the clearest explanation of the concepts involved. Although choosing primary material in this manner may appear to preclude accommodating a variety of learning styles, it, in fact, exposes students to a diversity of approaches to the physiology involved. Thus, the resource base with which the student becomes familiar is expanded.

A study guide (Fig. 1) listing appropriate textbook pages, placement of review questions and laboratory exercises, and study benchmarks is included to provide direction in working through the module. Topics covered are the same as those covered in the more traditional Lecture-Discussion course. The review questions and problem sets (see below) serve as learning objectives and provide indications of the depth of coverage expected by the student.

#### Review questions - Problem sets

To provide an active problem solving experience, a set of review questions-problems was developed for each subject area using latent image materials (5, 6). The latent image technique employed uses standard spirit duplicator masters (ditto) in conjunction with masters developed by A. B. Dick Company. The finished printed page contains areas that have visible print and areas that appear blank (Fig. 2A). When the apparently blank area is rubbed with a special pen, the information created with the latent image master is developed. The format of these sets is demonstrated in Figure 2. A problem is presented followed by a

#### STUDY GUIDE - NORMAL PHYSIOLOGY

- Introduction Comroe pages 1-7, Slonim and Hamilton pages 27-37 This should give you a feel for the necessity of a respiratory system and its functional anatomy.
- II. Mechanics
  - A. Lung volumes and capacity Comroe pages 13-16 Terminology necessary for further discussion of the system and for assessment of pulmonary function.
     REVIEW QUESTIONS — Lung volume and capacities
  - B. Muscles of respiration Comroe pages 95-98 Review the muscle groups involved in generation of a breath.
  - C. Static relationships (no flow conditions) Elastic properties of the lungs – Murray pages 78-85 (on reserve at SPC Office.)

NOTE; Equations 2,3, and 4 on pages 79 and 80 should indicate a CHANGE IN PRESSURE in the denominator---i.e. a change in the pressure difference across the structure.

More on surface forces and lung recoil - Comroe pages 105-115

Elastic properties of the chest wall - Murray pages 85-86 (on reserve at SPC Office.)

Elastic properties of the total system -- Murray pages 86-95 (on reserve at SPC Office.)

**REVIEW QUESTIONS** - Statics

"LABORATORY EXERCISE" – Computer model #1 COMPL Note: in this exercise, distending pressure is the pressure difference across the whole system. The volume change indicated is the volume change FROM FRC that would occur as a result of the applied distending pressure.

At this point, you should be familiar with and understand how the elastic properties of the lung and chest wall interact to determine the elastic properties of the respiratory system. In addition, you should be able to predict how changes in lung or chest wall mechanics should affect RV, VC, and resting FRC.

 D. Dynamic relationships (mechanics during airflow conditions) Resistance to flow, flow-volume relationships, dynamic compression – Murray pages 96-104 (on reserve at SPC Office.)

Types of airway obstruction and their diagnosis  $- \mbox{ Comroe}$  pages 131-138

Effects of increased airway resistance - Comroe pages 138-139  $\,$ 

REVIEW QUESTIONS — Dynamics "LABORATORY EXERCISE" — Computer model # 2 DYNAM

E. Work of breathing - Slonim and Hamilton pages 65-67

REVIEW QUESTIONS — Work of breathing "LABORATORY EXERCISE" — Computer model # 3 WINSP At this point, you should be able to predict the physiological consequences, in terms of mechanical changes, that might occur as a result of pathological processes affecting lung parenchyma, airways, or the chest wall.

- III. Alveolar gas exchange
- Fig. 1. Excerpt from module study guide. Latent image review questions and laboratory exercises are recommended as indicated. Study benchmarks are also included providing additional direction.

Α

#### H. Modell, Tutor

#### VII. TISSUE GAS EXCHANGE

Let us consider a number of animal experiments to review gas exchange.

Experiment 1

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\* \*

The preparation consists of an isolated limb set up so that we can control its perfusion. In addition, we have electrodes placed so that we can stimulate the muscles in the limb. Under resting conditions, the preparation requires 10 ml  $O_2/min$  and produces 9 ml  $CO_2/min$ . We perfuse it with hemoglobin free plasma with a  $Po_2$  of 100 Torr at a rate of 100 ml/min.

Can we supply enough  $\boldsymbol{\theta}_2$  under these conditions to maintain the tissue's metabolism?

\* <u>B</u> Can we supply enough  $0_2$  under these conditions to maintain the tissue's metabolism? \*NO\* <u>C</u> Can we supply enough  $0_2$  under these conditions to maintain the tissue's metabolism? \*NO\* \*0.0031 (ml 0,/100 ml plasma)/Torr can be dissolved in plasma. \* D Can we supply enough  $0_2$  under these conditions to maintain the tissue's metabolism? The plasma contains \*N0\* 1\*0.0031 (m1 0,/100 ml plasma)/Torr can be dissolved in plasma.  $0.0031 \times 100 =$ 0.31 ml 0,/100 ml plasma. We are delivering 0, at a rate of 0.31 ml 0,/100 ml X 100 ml/min or  $3^{2}$ ml  $0_{2}$ /min So metabolism can't be maintained under these conditions. Although a sufficient Po<sub>2</sub> is necessary to provide the driving force for gas exchange, the  $0_2$  content must also be high enough to provide sufficient  $0_2$  to maintain tissue metabolism.

Fig. 2. Example of latent image review problem format. Panel A. Problem set page as it appears before using latent image pen. Panel B. Student has used pen to see the correct answer to the problem. Asterisks indicate the

beginning and end of the hidden text. Panel C. Student has used pen to seek additional information concerning the problem. Panel D. Student has developed the portion of the page containing the solution to the problem.

"blank area" divided into three sections. Asterisks indicate where the hidden text begins and ends in each section. Developing the extreme left of the page reveal the correct answer, additional information concerning the problem is available in the middle of the page, and the correct solution can be developed in the space at the extreme right of the page. Thus by the use of the latent image pen, immediate feedback is available at three levels, and the student may be directed toward the correct solution. Unlike the more traditional problem-solution format, the student is afforded a greater opportunity to arrive at the correct solution before it is presented to him. The overall experience is similar to that gained from a question-answer type computer aided instruction problem set except that the time and terminal restrictions of the computer have been removed.

#### "Laboratory" exercises

To provide a means by which students can reinforce their learning by reasoning from basic facts to general concepts, a set of small, steady-state computer models of respiratory function are made available as "laboratory" exercises (3, 4). Each model focuses on one or more aspects of the respiratory system. Direction for each exercise is given in a "laboratory" manual that includes the scope of the study, labelled axes for data analysis, and a series of questions concerning interactions within the physiological system. Students are encouraged to run the lab exercises when they complete the appropriate subject area rather than waiting until all of the reading and review questions have been completed (see Fig. 1). A sample computer output from one exercise is shown in Figure 3. The model for this laboratory allows the student to examine the effects of intrapulmonary shunt flow on arterial and mixed venous blood-gas status. The model is a single compartment lung in a resting "subject" (oxygen consumption = 300 ml/min, carbon dioxide production = 240 ml/min). The student describes the subject by providing values for the per cent oxygen in inspired gas, alveolar ventilation, cardiac output, and the per cent of the cardiac output that is shunt flow. This student has chosen to examine the effects of increasing alveolar ventilation when 30 per cent of the cardiac output is shunt flow. The data indicate that, although alveolar oxygen tension and blood oxygen content increase as would be predicted, the increased alveolar ventilation has resulted in decreased blood oxygen tensions. Hence, by increasing ventilation, the pressure gradient for oxygen diffusion at the tissue level was reduced. Questions in the laboratory manual direct the student's attention to the interaction of the oxygen and carbon dioxide dissociation curves. By observing the effect of the increased ventilation on the blood carbon dioxide tensions, the student is able to explain the observed phenomenon and consider the physiological consequences of the interactions.

#### Discussion

The module has been offered as part of the Self-Paced Curricular Track (SPCT) for the past five years. During this time, approximately 90 students have completed the course. Although the module has evolved somewhat with respect to primary resource material, the basic features of the active learning experiences have remained intact throughout this period. In designing an evaluation scheme for the module, it was necessary to establish the basis for evaluation. Two general options were available We could try to ascertain whether this approach led to better success than the Lecture-Discussion on a variety of objective tests, or we could try to evaluate the module on the basis of how the student perceived the learning experience in terms of his learning style. We felt that the latter would provide the more accurate assessment since the SPCT population is self-selected, and controls necessary to eliminate the numerous variables not related to the course were not feasible. Hence, each student, upon completion of the course, was asked to complete and return a questionnaire dealing with various aspects of the module. Questions were posed or statements were made so that the student rated agreement with the statement or quality of the item on a scale of 1 to 5, 1 being strong disagreement or a very poor rating, 5 being strong agreement or an excellent rating. Because the questionnaire evolved with the course, a number of items were not asked of the first group going through the module.

A

В

NORMAL AND ABNORMAL LUNG FUNCTION PROGRAM 9 SHUNT COPYRIGHT, AMERICAN THORACIC SOCIETY 1975

PER CENT INSPIRED 02 ?21 ALVEOLAR VENTILATION (L/MIN) ?5 CARDIAC OUTPUT (L/MIN) ?6 PER CENT SHUNT ?30

30
VEN
50.4
54.6

CHANGE ?VA ALVEOLAR VENTILATION (L/MIN) ?8

CHANGE ?GO

CONDITIONS:	PCT INS VA= 8	P 02=	21	(PIO2= 149) Q= 6	SHUNT	= 30
	0 ALV	XYGEN ART	VEN	ALV	O2 ART	VEN
TENSION: CONTENT: SATURATION:	116.6	55.7 18.2 89.9	32.8 13.2 65.8	25.9	28.1 43.1	33.3 47.1

Fig. 3. Example of output from one "laboratory" exercise. Panel A. Student has provided values for per cent inspired oxyen, alveolar ventialtion, cardiac output, and per cent cardiac output that is intrapulmonary shunt. The computer repeats the description and provides data concerning alveloar and blood gas status. Panel B. Student has increased alveolar ventilation to 8 1/min. By comparing the two outputs, he can examine the physiological consequences of the altered ventilation (see text).

Approximately 44 per cent of students receiving the questionnaire returned it. This is about the average return rate for all questionnaires distributed to our student population. Repeated attempts by the Office of Research in Medical Education at this institution to determine if evaluations returned voiced representative feelings of those students not returning evaluations have indicated that the response is an accurate representation of the overall class opinion. Hence, we feel that the information obtained from our questionnaire reflects the opinions of the entire population taking the course.

The course has consistently been well received by the SPCT students. Eighty-six per cent of those responding to the questionnaire rated the module very good or excellent. The format of the review questions was seen as more helpful than if only solutions to the problems had been provided in a more conventional manner (71% indicated strong agreement with the statement). Eighty-one per cent agreed that use of the latent image as a mode of presentation was superior to other modes (e.g. presenting the same type of experience on the computer).

Response to the laboratory exercises has been quite interesting. In response to the statement, "The laboratory exercises were useful in organizing concepts," seventy-one per cent ranked their degree of agreement as 4 or 5. Some students (27%) listed the laboratory exercises as the most valuable learning experience in the module, and 46% indicated that they extended the scope of their studies with the models beyond that prescribed by the laboratory procedures. However, forty-three per cent listed mechanical aspects of the computer exercises (time, terminal accessibility, computer down-time, etc.) as the least valuable experience in the module. This response most likely reflects the high premium that these students place on their time expenditure and their interpretation of the Self-Paced curriculum as an "independent" experience. Although these students perceive the time spent at the computer terminal as "wasted," they reported that they spent approximately 40% of that time thinking about the physiological system rather than dealing with the computer per se.

In developing this course, we have attempted to demonstrate one way in which a variety of materials may be used to promote active learning experiences in an independent study setting. Use of latent image materials is relatively inexpensive, and they provide a great deal of latitude in format design for problem sets and case simulations. The computer models used as laboratory exercies in this module are also relatively inexpensive since they are small enough to run on minicomputers and many of the newer microcomputers.

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#### SYMPOSIUM ON THE TEACHING OF RESPIRATORY PHYSIOLOGY TO MEDICAL STUDENTS

Held at the Fall Meeting of the APS in Toronto, October, 1980

John B. West

Section of Physiology, M-023 University of California, San Diego

# INTRODUCTION

This symposium was sponsored by the Education Committee of the American Physiological Society. The objective of the symposium was to show how some medical schools go about the business of teaching respiratory physiology to medical students. The emphasis was not so much on what could be done with unlimited resources, but what is actually done in view of the various constraints such as available time, number of faculty, and financial resources.

Contributors were selected from four institutions thought to represent a range of approaches to the teaching of respiratory physiology to medical students. They were: E.J. Moran Campbell, M.D., McMaster University Medical School, Hamilton, Ontario, Canada; Robert E. Forster, M.D., University of Pennsylvania School of Medicine; Johannes Piiper, M.D., Max-Planck-Institut for Experimental Medicine, Göttingen, Federal Republic of Germany; and John B. West, M.D., Ph.D., University of California, San Diego Medical School.

The format of the symposium was somewhat unusual. During the first half hour there was a poster session in which the four contributors manned posters describing their approach. Some handouts were available at this time. This was followed by a one hour session during which each contributor was given 15 minutes to describe his approach to the teaching of respiratory physiology. The symposium concluded with another one half hour of poster session. This format allowed people with a somewhat peripheral interest in the subject to get the gist of the material by attending the oral presentations, while those who wanted more information could talk to the speakers before and after the formal presentations while they were manning their posters.

#### TEACHING OF RESPIRATORY PHYSIOLOGY AT THE UNIVERSITY OF CALIFORNIA SAN DIEGO SCHOOL OF MEDICINE John B. West, M.D., Ph.D.

At UCSD Medical School, medical students are taught respiratory physiology during the core course entitled "Organ Physiology and Pharmacology" given during the second (winter) quarter of the first year. This course follows the fall quarter course "Cell Biology and Biochemistry" during which some principles of general physiology are taught, including the physiology of the cell, properties of cell membranes including transport, and some aspects of nerve transmission and muscle contraction. The Organ Physiology and Pharmacology course covers cardiovascular, respiratory, renal and gastrointestinal physiology and pharmacology. Endocrine, reproductive and metabolic physiology are taught in a separate smaller course in the spring quarter during which neurophysiology is also taught in conjunction with other aspects of neurosciences. Pathophysiology is taught in the second year.

The components of the respiratory physiology course include formal lectures, laboratory sessions, discussion groups, recommended texts, other teaching aides, evaluation of the students, and evaluation of the course by the students. *Formal Lectures.* In most years 14 formal lectures are given. Since the course is only allocated 6 working days, 2 lectures are given on each day from 8 to 10 a.m. and on the first day there are an additional 2 lectures in the afternoon. The subjects of the lectures are: structure and function of the lung, ventilation, gas transport by the blood, acid base balance, diffusion, pulmonary blood flow, ventilation-perfusion relationships (2), mechanics (statics), mechanics (dynamis), control of ventilation, defenses of the lung, and respiration in unusual environments (2). Each lecture lasts 50 minutes. The emphasis is on the principles of physiology though clinical examples are used.

Laboratories. 2 afternoons in the 6 days are devoted to laboratories. The class of about 128 students is divided into 6 groups who rotate through 6 laboratory stations (3 in each afternoon). This means that each student spends about 1 hour at each station. Laboratories are principally demonstrations in which the students participate. The students have already attended 4 laboratories during the cardiovascular section of the course where they had the opportunity of working with anesthetized dogs in small groups.

The topics of the laboratories are as follows: spriometry-lung volume, flow volume curve; exercise-cardiorespiratory responses measured on a bicycle ergometer; diffusing capacity- as measured with carbon monoxide; control of ventilation- measured by rebreathing methods; single breath nitrogen washout-discussion of deadspace, alveolar gas; pressure-volume curve of isolated lung-also demonstration of surface tension.

*Discussion Groups.* The class is divided into 6 groups of about 20 students each. Each group is led by an experienced faculty member. Initially, discussion centers on problems arising from the lectures. In addition, questions for discussion are distributed ahead of time so that the students can prepare for them. The preferred procedure is for the faculty member to develop a question and answer dialogue with each student in turn, going in an orderly fashion around the group.

*Texts.* The principal text is "Respiratory Physiology-The Essentials" by J.B. West, second edition, Williams & Wilkins, 1979. In addition, "Physiology of Breathing" by J.H. Comroe, second edition, Yearbook, 1974 is recommended.

*Teaching Aids.* We show the film "Principles of Respiratory Mechanics, Parts I and II" made by the Department of Physiology, Harvard School of Public Health. Although this is old and somewhat out of date in some respects, the students find it helpful especially with the difficult notion of intrapleural pressure. The slide tape series "Illustrated Lectures in Respiratory Physiology," J.B. West, AV/MD, New York is also used, especially by the weaker students.

An informal quiz is given on the last day of the respiratory physiology course using a button operated student response system. Standard format multiple choice questions are projected onto a screen and the students select their answer. The faculty member can see the percentage of students selecting each possible answer but cannot identify individual student's responses. Where a substantial proportion of the class have selected the wrong answer, the question is discussed. This is a very popular feature of the course. *Evaluation of Students*. A one hour multiple choice exam (50 questions) is given following the respiratory section of the course. Standard format questions are used. In addition, a two hour multiple choice exam is given at the end of the Organ Physiology and Pharmacology course, and this includes some respiratory physiology. A pass/fail grade is given. Students who fail the course are given the option of taking a make-up exam at the end of the summer during which tutorial help is available. Any student who fails the make-up exam has to repeat the course. Between 0 and 3 students have done this in past years.

*Evaluation of the Course.* Evaluation forms are given out at the beginning of the Organ Physiology and Pharmacology course and are handed in by the students before each exam. All aspects of the course are evaluated, including lectures, laboratories, discussion groups, texts, teaching aids, and examinations. These evaluations are used to modify the course in subsequent years. It should also be noted that the Organ Physiology and Pharmacology Course Committee has three student members. They are a first year medical student, second year medical student, and a graduate student. This course is also taken by graduate students in the Physiology Ph.D. Program.

#### TEACHING OF RESPIRATORY PHYSIOLOGY AT McMASTER UNIVERSITY

#### E.J. Moran Campbell, M.D.

General Organization. The undergraduate curriculum is broken up into four "phases." In Phases I and II, which occupy ten weeks each, the student is given an overview of normal growth and development and is introduced to general responses of cells, tissues, and the organism. In Phase III which lasts 40 weeks, an organ-system approach is taken, and the most concentrated exposure to respiratory physiology occurs here, during a five week respiratory unit.

Problem Based Learning and the Tutorial Group. An important feature of learning at McMaster is the tutorial group, consisting of five students and a tutor. Generally this meets twice a week and in a 2-3 hour period examining various forms of biomedical problems. Real patients have been used, as well as simulated patients and computer models, but the problems generally are consise "paper" problems designed to stimulate both thinking about basic processes and the pursuit of additional relevant information.

The objective is not to arrive at a diagnosis but rather to achieve some understanding of the underlying pathophysiology.

In the respiratory unit a number of problems relating to various aspects of respirology are provided and these are usually "boxed" with a short history, x-rays, pulmonary function and other tests, pathological material, etc. The choice of problem, and the approach to it, is determined by the group under the leadership of the tutor.

The tutor may not be an expert in the field and is not expected to function as such, but ideally, to be one among the group of students, who like them, does his homework, but has perhaps a little more experience.

The Respiratory Unit. As is the case with other organ-systems, such as cardiology` and nephrology, the respiratory unit is presented four times during the 40 weeks of Phase III, for a different group of 25 students. The first group starting the respiratory unit, after only six months of medical school, will have less general background than later groups and may experience more difficulty with the concepts and content of the unit.

The unit is subdivided by weekly themes as follows:

- Week 1: The Respiratory Pump. Aspects of Structure and Development.
- Week 3: Pulmonary Gas Exchange and Blood Gas Carriage. Acid-Base and Control of Breathing.
- Week 3: A Closer Look at the Airways: Airway Dynamics and the Effects of Obstruction.
- Week 4: Lung Defenses and Lung Injury. Week 5: Pulmonary Function on Exercise Breathi
- Neek 5: Pulmonary Function on Exercise. Breathing at Altitude and at Depth.

A list of appropriate reading and audiovisual material is provided for each week and also suitable biomedical problems. With respect to reading material the books by West (Respiratory Physiology and Pulmonary Pathophysiology); Comroe's Physiology of Respiration; and a programmed text by Jones, (Blood Gases and Acid Base Physiology) have been found most valuable.

There are no formal lectures, but faculty members conduct a series of seminars on various aspects of respirology three to four times each week for the larger group of 25 students. The objective is not to cover the topics in depth, but rather to introduce them or to present subjects not adequately dealt with in standard texts.

Students are encouraged to visit the pulmonary function and exercise labs to familiarize themselves with the various procedures and to try some of the tests on themselves.

*Evaluation.* There are no formal examinations. The evaluation of each student is the responsibility of the tutor and the group, and depends chiefly on overall performance during the tutorial sessions. Students are expected to present, both orally and in writing, to the tutor, a satisfactory analysis of a biomedical problem.

*Criticisms.* The respiratory physiologist may feel short-changed in having to share time with pathologists, microbiologists, and the like, but five weeks is a generous period to devote to respirology. There is a possibility that too much is thrown at the students and it is a problem deciding what topics to present and in what detail. Should students have to work their way through the equal pressure point concept, and how familiar should they be with details of ventilation: perfusion relationships?

The lack of didactic teaching of basic sciences does present difficulties for the student without a science background who enters the respiratory unit at a disadvantage. It is a challenge to impart the concepts of respiratory physiology to such a student, but it can be done and most students do, in fact, achieve a reasonably good understanding of the subject.

There is some impatience on the part of students to acquire clinical experience early and this may detract from the hard work of developing an understanding of basic physiological and pathological processes. The basic science curriculum has to some extent been diluted by this demand and the course is perhaps more clinical than we would like.

It should be emphasized that what we are attempting at McMaster is not an entirely new departure, but a development of what was best in the classical system, that is small group and problem or patient based learning. We have discarded what was least productive, the formal lecture, the study of basic science divorced from the patient, and the practice of copious memorizing of facts.

#### TEACHING OF RESPIRATORY PHYSIOLOGY AT THE SCHOOL OF MEDICINE AT THE UNIVERSITY OF PENNSYLVANIA R.E. Forster, M.D. and A.B. Fisher, M.D.

The University of Pennsylvania developed a new curriculum approximately ten years ago, the philosophy of which was to present a modestly integrated and required core of basic science in the first year after which the students went on to required clinical courses. They are required to take additional basic science instruction and it was hoped that with some clinical experience the students would have a greater appreciation of the need for this material and elect to take additional courses in it. Of course it has not worked out this way. The students press to have more clinical studies substituted for their advanced basic science requirements and a sort of compromise has been reached by developing a series of applied basic science courses which are technically electives but which almost all students take. Interdepartmental 205 is an example of one of these courses.

Instruction in respiratory physiology at the University of Pennsylvania can be summarized in Table I.

Table I.	Summary	of '	Instruction	in	Respiratory	y Physiology
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	1st Yea	r	2nd Year	3rd or 4th Year	
	Physiology (Required)		Interdepartmental (Elective)	Pulmonary Medicine (Elective)	
Course Name	100 or	101	205	364A	
% of Class	90	10	96	33	
Duration (of Respiration)	2 wks	2 wks	2 wks	4 wks	
Total Hours	13	11	30	4 (Applied Physiology)	
Lecture	6	6	15	-	
Conference	4	6	13	4 (Applied	
Laboratory	3		2	Physiology	

Approximately 90% of the medical student body elects the course during the second year (Spring semester) and virtually all eventually take it. In the near future the course may become a required part of the curriculum.

The respiratory section of the course is two weeks in duration out of the total course duration of 8 weeks. The faculty is drawn primarily from Physiology and Medicine with some input from Anesthesia, Pediatrics, and Surgery. The emphasis is on applied physiology as opposed to pathophysiology of diseases. The respiratory section runs three hours a day for 10 days making a total of 30 hours of instruction. This include 13 lectures and runs the gamut of pulmonary physiology from review of normal lung structure and function to the basic concepts of lung mechanics, gas exchange and pulmonary circulation, and alteration of lung function in the presence of disease. Five workshops are scheduled with slides of x-rays and pathology. There are approximately 20-25 students in each workshop and the same instructor is responsible for all five workshops. On the final day of the course, students attend the pulmonary function laboratory for a first hand observation of testing. In addition, they are offered various elective conferences on this final day primarily dealing with environmental and occupational factors related to lung disease.

The final exam for the whole eight week course generally includes 25 multiple choice questions related to respiration. The students have the option of taking the exam home and being graded on a pass/fail basis, or taking the examination in class with grading on an honors, pass, fail system. Approximately half the class elects each of these options. The boundary between Chest Medicine and Respiratory Physiology is not sharp and we have included four hours of instruction particularly related to pulmonary function and its testing generally offered in the Pulmonary Medicine elective in Table I.

#### TEACHING OF RESPIRATORY PHYSIOLOGY TO MEDICAL STUDENTS AT THE UNIVERSITY OF GÖTTINGEN (FEDERAL REPUBLIC OF GERMANY) Johannes Piiper, M.D.

I. It is appropriate to point out the different background of German medical students, which is in great part due to the different school system in Germany (which is similar to those in other European countries). The main school type leading to university has 13 year-grades: 4 years of elementary school, 9 years of secondary school ("Gymnasium"). There is no equivalent of the American college. The graduation from secondary school is by a school-leaving examination ("Abitur"). The average mark of the school-leaving certificate is decisive for admission to medical school (which is granted by a central government agency for all medical schools in W. Germany). Only a limited percentage of applicants obtains admission to medical study.

II. The study of medicine in German medical schools comprises 4 sections: (1) pre-clinical - 2 years, (2) clinical part I (mainly theoretical clinical subjects) - 1 year, (3) clinical part II (clinical medicine) - 2 years, and (4) internship - 1 year; total 6 years. After each of the sections a written examination (of multiple choice type) has to be taken, only the last examination comprises an oral section. The pre-medical exam (after 2 years of pre-clinical study) comprises all subjects studied during these years: physics, chemistry, biology, anatomy, histology, embryology, physiology, biochemistry, medical psychology and medical sociology. Only the overall score counts (this means that a student having no single correct answer in physiology may easily pass the exam).

III. Physiology is taught in the second pre-clinical year which is subdivided into two semesters: summer and winter semester. In both semesters a course in physiology I (heart, circulation, respiration, bioenergetics, thermoregulation, kidney, water and electrolytes, hormones, gastrointestinal tract) and a course in physiology II (central nervous system, nerve, muscle, sense organs) are given, each comprising a lecture course of about 66 hours and a laboratory course of about 90 hours. Besides there are some (nonobligatory) seminars and special lectures courses.

IV. 15 hours of the 66 hours in lecture course Physiology I are on respiration. The usual schedule is (in brackets, number of lecture hours): introduction and lung volumes (1), mechanics of breathing (2), pulmonary gas exchange (4), blood  $O_2$  and  $CO_2$ (2), acid-base balance (2), control of breathing (2), tissue respiration (2). The lecture course is scheduled to be attended by 300 medical and dental students (the real attendance is usually much less). In the laboratory course there is a 6-hour laboratory on respiration (measurement of lung volumes, including residual volume, and of pulmonary gas exchange using spirometry, infrared  $CO_2$  and paramagnetic  $O_2$  meters), to be repeated 15 times per semester to groups of about 18 students each. Teaching of respiratory physiology occupies about 10-15% of the total teaching of physiology. August W. Jaussi Department of Zoology Brigham Young University Provo, Utah 84602

A discussion of blood pressure and flow requires consideration of several simultaneous events, i.e., cardiac output (which in turn is the result of stroke volume and heart rate), peripheral resistance, blood velocity and the influence of vessel compliance or elasticity. The relationship between flow in ml/minute (Q), pressure (P) and resistance (R) is expressed by  $Q = \frac{P}{R}$ . Compliance, which can change with sympathetic activity or with age, although not a part of this relationship does have an influence of one of these variables generally assumes that the other variables are held constant. On the other hand, beginning students find it difficult to visualize two simultaneous variables.

Model systems and programs<sup>1</sup> have been designed to help the student understand circulatory behavior as well as the effects of certain variations on blood flow. We describe here a simple, economical model for illustrating the effect of changes in cardiac output, peripheral resistance and compliance on arterial blood pressure. Also, an illustration is presented of results obtained when changes are made in these parameters.

The complete system is diagrammatically represented in Figure 1. The heart is represented by a 3 ml disposable plastic syringe (A). Two one-way plastic valves (B), one attached to a side tube from a water reservoir and the other just beyond this side tube permits one-way flow through the system. (A 3-way stopcock may be placed between the syringe and the reservoir side tube for easier removal of air bubbles.) The regulated elastic component of the system consists of a 1/2" I.D., 1/16" wall, amber rubber tubing (D) that is just long enough to pass through a 5/8" hole



Fig. 1. Illustration of the simple hemodynamic model. Letter indications are described in text.

drilled lengthwise between two 8-10" long 1" thick blocks of wood (C) that are clamped together. Each block has a groove that provides half of the completed hole. When placed around the tubing the blocks are clamped by four 3/8" bolts fastened with wing nuts. To assure positive separation of the blocks when the wing nuts are slacked off, small springs are placed on each bolt between the blocks. A recess at each bolt hole permits the blocks to still be clamped tightly together.

Depending upon the total amount of elasticity desired, the rest of the tubing is either 5/32" I.D. tygon or amber rubber tubing (E). One or more "Y" tubes permits a reduction to 3/64" rubber tubing and provides peripheral pathways to which adjustable pressure clamps are attached (F).

After the system is filled with water and the air bubbles removed the wing nuts on the elasticity control blocks are turned until the desired degree of stretch by tubing D is permitted. In a similar manner the peripheral resistance clamps are set. This latter step will require one or two trial and error adjustments so that pressure will remain within the desired limits. By forcing the syringe plunger in rhythm with a metronome or similar timer, the syringe operator at the same time can regulate stroke volume by observing how far he withdraws the plunger between pushes. We have found that stroke volumes ranging from 0.5 to 2.0 ml with rates up to 80/minute can be attained with a fair degree of accuracy and consistency. With prolonged use the syringe becomes more difficult to operate and should be replaced. Pressure may be recorded with any system one has available, or by closing the pressure side tube and then measuring the relative distances that water is ejected from the ends of the capillary tubes.

The results shown (Fig. 2) are from recordings using two levels of resistance and two of total elasticity, each with four different flow rates (cardiac outputs): (a) low resistance with high elasticity, (b) low resistance with low elasticity, (c) high resistance with high elasticity and (d) high resistance with low elasticity. At each of these settings the stroke volume is sequentially 0.5, 1.0, 1.5 and 2.0 ml each at a rate of 60 beats/minute. Thus flow rate is 30, 60, 90 and 120 ml/minute.



Fig. 2. Pressure recordings and calculations of parameters following variations in flow, peripheral resistance and compliance of the hemodynamic model. Note the slightly increased pulse pressure at Q = 120 in c compared to that in a indicates a decreasing elasticity of the vessel at the higher pressure. (Q = flow in ml/min., MP = mean pressure, mm Hg., RU = resistance units, arbitrary, see text).

For example see, Greenwald, L., A do it yourself heart. *Physiol. Teach.* 4: (No. 2) 3, 1975, and Rothe, C. F., A computer model of the cardiovascular system for effective learning. *The Physiologist*, 22: (No. 6) 29-33, 1979.

#### CONTRACTURE OF SKELETAL MUSCLE BY CAFFEINE -PROBE FOR CALCIUM ACTION Allen Isaacson Biology Department William Paterson College Wayne, New Jersey 07470

The contraction of isolated skeletal muscle in response to an electrical stimulus, applied either to nerve fibers innervating the muscle, or directly to the muscle itself, is a popular demonstration in student laboratories in physiology courses.

The spontaneous, voluntary contractions of *in vivo* skeletal muscle are ordinarily elicited by action potentials [propagated waves of reversible depolarization and repolarization of muscle cell membranes (sarcolemmal and T-tubular)], evoked through impulses delivered by means of voluntary nerve fibers that connect to muscle fibers. Use of electrical stimuli in the laboratory to evoke contraction of muscle thus illustrates reversible responses of muscle that are similar to the physiologically occurring spontaneous, neurally elicited responses of skeletal muscle.

There is an active area of research that deals with excitationcontraction coupling (E-CC) (Sandow, 1952; Ebashi, 1976). E-CC relates in time the measurable events that ensue in muscle following electrical excitation and that lead to a contraction. Mechanical responses are measured isometrically as a development of tension or, (Fig. 1) (Isaacson and Sandow, 1963<sup>1</sup> more often in student laboratories, as a shortening of the whole muscle recorded while the muscle lifts a fixed load (isotonic contraction).



E-CC intimately involves calcium that is stored in vescicles of the sarcoplasmic reticulum in resting skeletal muscle and appears internally following electrical stimulation of muscle (Blinks, Rüdel and Taylor, 1978) as Ca++ cations. Direct evidence of Ca++ release in muscle requires use of procedures relatively complicated for student laboratories, for example, Ca<sup>45</sup> radioisotope labelling (Shanes and Bianchi, 1960) or microinjection into a muscle fiber of the Ca++ sensitive bioluminescent protein aequorin (Blinks et al., 1978; Taylor and Godt, 1976).

However, students can easily infer a role for Ca + + release in muscle by using caffeine added to normal Ringer's solution to produce contractions of skeletal muscle. A still interesting early study of caffeine action on muscle was performed by Hartree and Hill, 1924. These responses are termed contractures and appear to be independent of the electrical potential of the surface (sarcolemma) membrane of muscle fibers (Axelsson and Thesleff, 1958; Bianchi, 1961; Isaacson and Sandow, 1967a), and yet they are mediated by Ca + + release. More recent studies of isolated human skeletal muscle have used caffeine to analyze Ca + + regulation of contraction in normal and dystrophic muscle (Wood et al., 1978; Wood, 1978).

A simple procedure to demonstrate contracture effects of caffeine, is to dissect out the sartorius muscle of the frog leg and immerse this muscle in control Ringer's solution and subsequently into the same solution but with an added 10 mM (2 mg/ml) of caffeine. Within a few minutes, caffeine readily penetrates into the depths of the multifiber sartorius muscle (Bianchi, 1962; Isaacson and Sandow, 1967b) and causes the muscle to shorten to about 1/3 of its rest length (Fig. 2 (Bianchi, 1968). The sartorius muscle gives a much more dramatic shortening effect than the gastrocnemius muscle when exposed to caffeine. So it is worth the effort to use the sartorius rather than the traditional student laboratory muscle (gastrocnemius).



Cross sectional area of sartorius mucles of medium size 2½ to 3 inch frogs typical of these experiments is approximately 0.03cm<sup>2</sup>, i.e., these muscles are about 0.05cm thick and 0.6cm wide. So the peak tetanus tension of about 80g is about 2640g/cm<sup>2</sup>. Likewise, the peak caffeine contracture in this tracing of about 8g, yields about 264g/cm<sup>2</sup>. Average thickness of sartorius measured from weighings of muscle at end of experiment and tracings of muscle width and length (Isaacson, A., 1961, Effects of zinc on responses of frog skeletal muscle, Ph.D. dissertation, New York University, New York, Fig. 5, p. 51).

Some recent studies with the electron microscope show that caffeine (10 mM) disrupts sarcoplasmic reticular membranes (SR) of skeletal muscles (Huddart and Oates, 1970). Frog muscles, previously exposed to caffeine (5 mM), have been shown to have much greater space accessible to externally applied C<sup>14</sup>-labelled sucrose (a normally membrane impermeant compound) used as a probe to measure the extracellular space of whole muscle (Isaacson and Bárány, 1973; Isaacson and Bárány, 1974). A simple inference from studies that show caffeine (5 mM) to rupture muscle membranes is that the internal release of large amounts of Ca + + may be owing to this same loss of integrity of the membranes of the SR.

This is suggested by the observation that sub-contracture producing concentrations of caffeine (1 mM) do not increase the space accessible to C14 sucrose in frog muscle (Isaacson and Barany, 1973). Also supporting this view of caffeine action, is the finding that, when applied together with caffeine (5 mM), procaine in a concentration of 3.67 mM (1 mg/ml) suffices to block contracture development (Feinstein, 1963). This concentration of procaine also blocks the disruptive effects of caffeine on the SR membranes of muscle as visualized by electron microscope (Uhrik and Zacharová, 1970) and as inferred with the extracellular space probe C<sup>14</sup> sucrose (Isaacson and Bárány, 1974). Similar experiments with contracture producing concentrations of quinine, chlorpromazine (Isaacson and Bárány, 1974) and prenylamine (Kirsten and Lustig, 1977) may be interpreted also as a result of their disruptive effects on SR membranes and consequent release of their stored amounts of Ca++.

For reasons of brevity the literature cited omits many valuable contributions that add new insights into the action of caffeine and related drugs. The bibliographies of papers cited here can be useful in finding further articles about caffeine.

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# CBE STYLE MANUAL 4th edition

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#### Dear Dr. Reynolds:

Since sending my previous letter (Physiology Teacher, October 1980) in which I commented on the Heusner and Tracy paper (Physiology Teacher, p. 47, June 1980) I have noted an important difference between their circulation model and the one I used. Perhaps, this will explain the difference in emphasis on the role of diastolic arterial volume in influencing pulse pressure.

Heusner and Tracy use a Starling Resistor (SR) to provide arterial compliance and to produce changes in compliance. To construct this a latex wound drain 1" in diameter is placed inside a glass cylinder 1" in diameter, then air is introduced via a sidearm into the space between the cylinder and drain tubing. When air is introduced and pressure correspondingly increased and the sidearm is closed elasticity is provided by air under pressure in the SR. The rubber drain serves only to separate the water and air; it would not be put under stretch at any internal pressure since its diameter when empty is the same as that of the glass cylinder. As shown in Fig. 6 and stated in the text the pressure-volume relation of SR, a rigid system, is found to be linear. This is predictable from Boyle's Law. If this were the only source of elasticity in their model changes in diastolic arterial volume would not produce changes in pulse pressure; a given stroke volume would give the same rise in pressure regardless of the volume into which it was introduced.

In our model the "arterial" side consisted of rubber tubing. In such a system each increment of volume produces a lesser increase of pressure than that produced by the preceding increment of volume (in our model about 10% less). This result is predictable from the volume-distensibility coefficient. Thus a given stroke volume added to the higher diastolic volume produces a lesser rise in pressure than the same volume added to a lower diastolic volume.

Despite the characteristics of the SR, and their statement that "the compliance of the system reduces to that of the SR," the Heusner-Tracy model still shows a decrease in pulse pressure when peripheral resistance is increased; and from this it may be concluded that some part of their model other than the SR shows a less than linear increase in pressure with increases in volume. This is not surprising since the model does include some distensible tubing.

One who constructs a model of circulation will need to decide whether it is preferable to obtain elasticity mainly or exclusively from compressed air in a rigid closed space or from distensible tubing. The latter would seem to be better to depict what occurs in the arterial tree which is being subjected to varying internal pressure and a relatively constant external pressure.

The pressure-volume curve for the arterial tree is complex. In the young mammalian arterial tree at lower pressures increments of volume produce a less than linear increase in pressure, while at higher pressures compliance progressively decreases and the increase in pressure with increasing volumes becomes greater than linear. In the sclerotic arterial tree the segment of the pressurevolume curve that shows a less than linear increase is shortened.

> Sincerely, W. B. Youmans Emeritus Professor of Physiology University of Wisconsin

The following letter was received in reference to the article "A Simple Inexpensive Method for the Measurement of In Vivo Intestinal Activity" by V.L. Sallee and J.F. Gaugl.

"The article by Sallee and Gaugl in October's <u>Physiology</u> <u>Teacher</u> brought to mind some lessons I learned about intestinal motility while a teaching assistant at U.C. Davis. The lab which had been used there involved placing a balloon in the intestine of a pentobarbitol anesthetized dog, and measuring pressure changes during various drug injections and vagus nerve stimulation. Except for our methods of measuring pressure, the experiment was much like that described by the above authors. We also found that the intestines were often inactive, which "produced student disinterest" as Sallee and Gaugl aptly state.

"We found three modifications which greatly improved the lab, making it much more informative and interesting. First, we discovered that rabbits have intrinsically more motile intestines, and thus make far better subjects than dogs. Second, barbiturate anesthetics inhibit intestinal motility, thus we switched to Halothane, using promazine tranquilizer to ease induction. The third change we made was perhaps the most important - we dropped the measurement of balloon pressure from the protocol! Instead, we brought a loop of intestine out through the abdominal incision and into an inverted plastic beaker which was sealed to the skin edge. The beaker was filled with saline through a fitting which also served to apply negative pressure to support the weight of the saline, preventing it from running into the abdominal cavity. Rather than watching a pen move on a chart recorder, the students watched the intestine itself, which allowed them to observe directly the changes in motility, the peristaltic nature of the contraction, and dramatic changes in color indicative of vasoconstriction or dilation. I feel that this is far more educational than the pseudo-quantitative measurement of pressure or volume displacement from a balloon. The same experiment could be done more simply by eliminating the chamber, if one took care to keep the intestine moist with saline and clear food wrap.

"There is a more general lesson to be learned here: We often become so enamored of the "hard copy outputs" of our beloved measurement and recording equipment that we forget how much can be learned by direct observation."

> Robert B. Banzett, Ph.D. Asst. Prof. of Physiology Harvard University School of Public Health

Shock, Physiological Surgery, and George Washington Crile; Medical Innovation in the Progressive Era. Peter C. English. Greenwood Press, Westport, CT., 1980. 271 pp., index., \$25.00.

This book by Peter C. English, a pediatrician and historian at Duke, describes the early ideas about the nature of shock, the contribution made to its understanding by George Washington Crile, the Cleveland surgeon, and the eventual devotion of many physiologists to analysis of shock and prescription for its prevention or treatment. The scholarship is impressive, indeed ostentatious, for there are 555 footnotes to the text, and the bibliography occupies 17.87% of the volume. Repeated misspelling of Henry Sewall's name, the wrong date for Newell Martin's death and similar minor errors somewhat undermine one's confidence in the absolute accuracy of the book. Crile believed that the chief function, or perhaps the only function, of a physiologist is to serve the clinician, and English has a certain tendency to imply that a person without clinical experience doesn't know what he is talking about. Nevertheless, the reader who takes it with a dash of isotonic NaCl, or more appropriately with a bit of 25% serum albumin, will be pleased and instructed.

There is no doubt of Crile's importance as a surgeon in the days when asepsis and anesthesia first permitted men with great technical competence and supreme self-confidence to establish major surgical clinics. English, however, presents Crile as the man who around the turn of the Century first recognized the central position of low blood pressure in shock and who, with missionary zeal, carried this message, together with his ever-shifting and always wrong ideas about the genesis and treatment of shock, to the surgical world.

I needed to be convinced of Crile's importance in this respect, for more than forty years ago I looked at his book on *The Phenomena of Life,* with its chapter by Otto Glasser on mitogenetic radiation, and I had written Crile off as an enthusiast in the grip of a preposterous idea. A more recent glance at the book and at an earlier one on the same subject, has not changed my mind. Nevertheless, English does make it clear that Crile started surgeons on what was to prove to be the right track to important practical achievements.

It is always a mistake to set up a biologist as a hero. The crudities of *Microbe Hunters* are obvious, but even in better books about the Mayo brothers, Pasteur, Pavlov or Bernard, there is a tendency to make the inevitable opponents out to be fools or knaves. English, in carrying his story through the First World War and into the 1920's, describes the work of many physiologists who found Crile's work wanting but who, like Crile, often themselves fumbled. In his chapter on the *Response of Professional Physiologists to Crile's Revolution*, English is reasonably fair to both sides, but he does come close to painting Yandell Henderson as a fool and W. T. Porter as a knave.

There is a book yet to be written about the later work which completed the story of shock, but in the meantime anyone interested in shock's history, or in the history of modern physiology, will want to read this book carefully and critically.

> H. W. Davenport, B.A. Department of Physiology The University of Michigan Ann Arbor, Michigan 48109

*The Pharmacological Basis of Therapeutics, 6th Ed.* A.G. Gilman, L.S. Goodman, A. Gilman, Eds. Macmillan Publ. Co., New York, 1980. 1843 pp., illus., index. \$45.00.

The newest edition of this classic pharmacology text will meet favorably with the expectations of most readers. Many sections of the text have been reorganized, newly authored, and some chapters are completely new. The first section chapter on pharmacokinetics is now accompanied by an appendix which discusses the design and optimization of dosage regimens, and includes tables of pharmacokinetic data for many drugs. A new chapter of pharmacodynamics discusses drug receptors and their properties, and a new chapter on the principles of therapeutics includes drug therapy and the regulation, development, and toxicity of drugs. The sixth edition has been reorganized with great success to introduce autonomic pharmacology in the second section. This new sequence allows for a progressive study of pharmacology, and the chapter on autonomics and neurohumoral transmission (authored by Steven E. Mayer) is a fine introduction to fundamental concepts of the science. The third section deals with drugs acting on the central nervous system. An introduction to brain regions of practical importance and the identification of central neurotransmitters has been included. Prostaglandins have achieved prominence in this edition, and receive expert introduction in a new chapter on prostaglandins, prostacyclin, and thromboxane (authored by S. Moncada, R.J. Flower, and J.R. Vane). The physiological functions of these compounds, as well as the lipoxygenase products, are discussed along with their biochemistry. Fittingly, these same authors have rewritten the chapter on analgesic-antipyretics and antiinflammatory agents. Digitalis and allied cardiac glycosides are in a newly authored chapter by Brian F. Hoffman and J.T. Bigger, Jr. These authors present an authoritative narrative of the cellular mechanisms of action of digitalis, as well as an interesting discussion of the effects of this drug on animal and human hearts in situ. These same authors are also responsible for the much improved chapter on antiarrhythmic drugs, which includes not only therapeutic agents but also a worthwhile introduction to cardiac electrophysiology and the mechanisms responsible for cardiac arrhythmias. The chapter on drugs used in the treatment of hyperlipoproteinemias has been rewritten with recent information on lipoprotein metabolism and coronary heart disease. The newly authored section on chemotherapy of microbial diseases includes a new discussion of therapy with combined antimicrobial agents. Drugs effective in megaloblastic anemias is newly authored and approaches the subject from the metabolism of vitamin B<sub>12</sub> and folic acid through the principles of therapy using these compounds.

The sixth edition includes a new section devoted to an introduction of the principle of toxicology, metal poisoning and therapy, pollutant toxicity, pesticides and insecticides. Thus, the new edition of *The Pharmacological Basis of Therapeutics* remains true to the goal of correlating modern pharmacology, physiology, and the medical sciences. The reorganization of the text and the expert contributions of many new authors have resulted in another vigorous and thorough treatise of pharmacological science.

> Suzanne G. Laychock, Ph.D. Med. Coll. of Virginia

*Mechanics and Thermodynamics of Biomembranes.* Evan A. Evans and Richard Skalak. CRC Press, Boca Raton, Florida, 1980. 254 pp., illus., refs., \$34.95.

The field of biomembrane mechanics is presented in this short treatise through the analysis of the membrane as a twodimensional molecular layer. The discussions are highly technical for engineers and physical scientists with interests in surface deformation analysis and the derivation of elastic constitutive equations from thermodynamic properties of membranes. Following discussions of mechanical equilibria of flat and axisymmetric membranes, isothermal constitutive equations, shear hyperelasticity, viscosity, relaxation, and viscoplasticity, the last section introduces biological membrane experiments designed to demonstrate the physical concepts. The phenomenon of area dilation produced by isotropic tension is interesting and well described with reference to biological systems such as the red cell. The deformation produced by membrane shear is discussed as an important concept with biological applications. Other sections describe the thermoelasticity and thermodynamics of cell membrances, area compressibility of multilamellar lipid phases and water, and viscoelastic recovery of distorted membranes. The text is described as tutorial since it is meant to develop in the reader specific mathematical skills and an appreciation and understanding of the methods of physical analysis.

> Suzanne G. Laychock, Ph.D. Dept. of Pharmacology Med. Coll. of Virginia

*The Human Organism.* 5th Edition. R.M. De Coursey and J.L. Renfro. McGraw-Hill, New York, 1980. 767 pp., illus., glossary, index, \$20.95.

The Human Organism is set apart from most introductory biology texts due to its rather unique topic choice and presentment. The text includes osteology and skeletal muscle anatomy as individual chapters, and together they comprise one of the most complete descriptions of skeletal and muscle anatomy to be found in an introductory text. The anatomical chapters in conjunction with the traditional subjects of cellular structure and enzymology, neurophysiology, endocrinology, circulation, respiration, and the physiology of the kidneys, digestive and reproductive systems, enhance the usefulness of this text as a paramedical or health-science related primer. Even the material presented in the traditional biology sections is designed to emphasize the structure and function of the organism. For instance, a thorough introduction to neuroanatomy is included in the section describing the central and autonomic nervous systems, and there is an inclusive chapter on the anatomy of the eye and ear in the section on special senses. Many diagrams, tables, and photographs greatly enhance the discussions which present the elementary principles of biology in a clear and concise manner. Each chapter concludes with a description of the pertinent clinical aspects, and also includes review questions and a suggested reading list. The different sections of the text complement each other, and overall present an interesting elementary, but thorough, introduction to the structure and function of the human organism.

Suzanne G. Laychock, Ph.D. Dept. of Pharmacology Med. Coll. of Virginia *Physiological Psychology.* Thomas S. Brown and Patricia M. Wallace. Academic Press, New York, 1980. 643 pp., illus., index, \$19.95.

With exciting research developments, with increasing recognition of the biological bases/correlates of behavior, and with relatively large scale undergraduate enrollment in psychology, college level courses are provided increasingly under various names like Physiological Psychology. In addition, the labels might be Biopsychology, Psychobiology, Biological Bases of Behavior, Neural Bases of Behavior, Brain and Behavior, Neuropsychology, Biological Psychology, Physiology and Behavior, etc. This book is a contribution to the growing textbook literature to serve these areas which are set mainly in the departments of psychology for junior/senior level students.

The authors are experienced psychology teachers at DePaul University and Clarion State College. The focus is on the relationships between physiology and behavior. The level is introductory, and does not assume an extensive background in biology, psychology, or related areas.

Fifteen chapters after the introductory chapter follow a plan, which starts with the neuron-axonal conduction and synaptic transmission. An overview of the neurons system centers on the brain, spinal cord, and the peripheral nervous system. They cover a chapter on the senses with an emphasis on vision, followed by treatments of audition, the chemical senses, and somatosenses and vestibular senses. Brain control of movement is considered in the next chapter, Chapter 9. The next four units deal with emotion, motivations (hunger and thirst, sex), and rhythmic behavior (sleep, arousal, attention). Chapters 14 and 15 are under the heading of Plasticity in the nervous system and deal with Development and Learning and Memory. The closing chapter deals with Higher Processes - the association cortex, average evoked potential, the split-brain, and language. Each chapter has an introduction, and each unit in the chapter has a summary. Each chapter lists key terms as well as several suggested readings. The appendix has a human brain atlas, a glossary, references and author and subject index.

The stage is set in the Introduction to the physiological bases of behavior by presentation of three major continuing issues: the mind-body problem, localization for function, and nature versus nurture. The style is clear, fundamental, and the references are current. The illustrations are freshly drawn, and are excellently done. The topics dealt with are appropriate. The general stance is on the relationships between behavior and physiology. The book appears to be usable, introductory, reasonably self contained, effectively organized and well presented. One could readily develop a variant of the concepts and relationships of importance, but this selection is suitable, and indicates the physiological base from a primary concern with behavior. From my view I wish that the authors had taken stock and closed with a status analysis of the major continuing issues.

> Sherman Ross Dept. of Psychology Howard University Washington, D.C.

*Thermoregulation.* Evelyn Satinoff, Ed. Benchmark Papers in Behavior/13. Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, 1980. xiii + 375 pp., \$45.00.

Dr. Evelyn Satinoff has produced a collection of key papers and excerpts of papers consistent in quality with other "Benchmark Papers" and books on behavior. The editor's organizational scheme follows, in general, the history of progress in thermoregulation research. The ultimate result of this volume is a collection of pertinent writings treated in a progressive and integrated pattern. The book is divided into six major parts. Each of the six parts contains a clearly written preface section by Dr. Satinoff in which she analyzes the papers in that part as a unit, including, when pertinent, information about other investigations. It is these concise discussions that pull together, in a single volume, some of the most significant research into the homeostatic mechanisms of temperature in animals.

Part I, "The Concept of Thermal Homeostasis" is introduced by an excerpt of Claude Bernard's writings on the constancy of the internal environment, followed by part of W.B. Cannon's paper on the constancy of body temperature. These and the two other papers in Part I introduce the background research in thermoregulation and follow this with ideas of the relationship of homeostasis and behavior, how reflexes and behavioral mechanisms interact in maintaining stability in desert animals.

Part II, "The Search for the Thermostat" begins with Isaac Ott's paper, written in 1884, which reports that temperature is controlled in the vicinity of the base of the brain. The other three of the four papers in this section follow the development of experimental proof, pointing out that the prioptic area of the brain with its many temperature-sensitive areas contains the thermostat.

Part III, "Evidence of Many Thermostats" contains six papers (written between 1933 and 1974) reviewing the research that shows that there is more than one specific center; there is a type of hierarchial control of various thermoregulatory responses in humans as well as in lower animals.

Part IV, "Fever" (four papers) contains discussions of the nature of fever, its probable causes and how poikilotherms control their thermoregulatory systems. These ideas lead up to the demonstration that fever is evolutionary. Intriguing is the similarity of mammalian neonates to lower vertebrates (reptiles) when neonates are allowed to thermoregulate behaviorally, (as is found in ectotherms). This Part lead directly into Part V, "Thermoregulatory Behavior" (six papers, written between 1837 and 1971 using insects, fish, reptiles, and non-human mammals as experimental subjects) in which is discussed various behavioral thermoregulatory activity responses among vertebrate and invertebrate animals.

Part VI, "Evolution" contains two papers, "The Origin of Theromregulation" by James E. Heath and "Possible Origin of Dermal Temperature" by Raymond B. Cowles, in which, as the editor writes, "Most, if not all, thermoregulatory responses evolved out of systems that were originally used for other purposes ..." These two papers "offer provocative and intriguing speculations about what those other systems might be for two of the most important mammalian thermoregulating responses."

This volume certainly deserves to be in the library of not only every biologist and behaviorist interested in homeostasis but also those interested in systematics, the latter because far too often systematists, and especially evolutionists, neglect physiology in their experimentation and analyses of the biology and behavior of animals. The book costs \$45.00 which, although by today's standards is not excessive, may be beyond the reach of students. However, I would suggest that the book be available to biologists and behaviorists in every life science library as a reference for the faculty and as required reading for advanced students. I strongly recommend this book of "Benchmark Papers"!

> George J. Jacobs Vertebrate Zoology Smithsonian Institution Washington, D.C.

*Mathematical Modelling and Computers in Endocrinology*. J.E.A. McIntosh and R.P. McIntosh. Springer-Verlag, New York, 1980. illus., tables, \$48.40.

All scientific investigations involve modeling at some level. To quote von Bertalanffy\* "The choice is not whether to remain in the field of data or to theorize, the choice is only between models that are more or less abstract, generalized, near or more remote from direct observation, more or less suitable to represent observed phenomena." The monograph by McIntosh and McIntosh provides theoretical and practical information for producing mathematically based models using computers. Material is presented in a crisp and precise style with the biologically trained reader in mind. A physiologist with modest recall of freshman calculus could profitably read this book.

One should not obtain this book expecting to find a comprehensive review of mathematical models in endocrinology. What he/she will find is a guidebook to modeling with examples drawn largely from the author's field of expertise, reproductive endocrinology. This is not necessarily a drawback since the examples deal with common areas of physiology where data meet theory including clearance and compartmental analysis, ligandmacromolecule interactions, and description of biological rhythms. Introductory sections of the book explain the use of differential equations in modeling and define terms such as: linearity, stability, feedback control, transient and steady state behavior. Parameter estimation and experimental design are appropriately discussed. Perhaps the strongest feature of the monograph is the emphasis on proper use of statistics to evaluate data and models. The authors stress this point, "Quantitative questions cannot be argued when no estimate of reliability is available." An appendix to the book includes complete FOR-TRAN programs used by the authors to develop and test their models. A novice modeler will want to consider other widely used computer aids to modeling, such as the SAAM program, which are only briefly discussed by McIntosh and McIntosh.

In summary, the readability and overall quality of the monograph is excellent. I enthusiastically recommend it to those planning to undertake mathematical modeling *and* to those who do not believe such techniques are of value. This book could serve as the basis for a useful graduate course on mathematical models in physiology.

<sup>\*</sup> General Systems Theory, 1973, Penguine University Books

*Renal Physiology* (2nd Ed). Arthur J. Vander. McGraw-Hill Book Co., New York, 1980. 200 pp., illus., index, paperback, \$7.95.

This book is written primarily for those wishing to learn basic concepts in renal physiology. In the preface, the author states, "This book is my attempt to identify the essential core content of renal physiology appropriate for medical students and to present it in a way which permits the students to master the material independently, i.e., with not (or very few) accompanying lectures by the instructor." This goal of presenting an essential core of renal physiology so that it can be independently mastered is admirably achieved. The fundamental concepts of renal physiology are clearly presented in a didactic fashion. Controversies in specialized areas are addressed in footnotes. The clear presentation along with study questions for each chapter that focus on difficult concepts or areas of confusion provide for independent mastery. Basic concepts in renal anatomy, renal hemodynamics, glomerular filtration, tubular reabsorption and secretion, renal clearance, renal handling of organic compounds, renal handling of electrolytes, renal regulation of sodium and water balance, and renal regulation of acid-base status are presented. Throughout the book, especially in the chapter concerning acid-base regulation, clinical examples are used to illustrate concepts. This book is particularly suitable for medical students, but is also of value for students in beginning courses in physiology.

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*Gastrointestinal Physiology – The Essentials.* Thomas Sernka and Eugene Jacobson. Williams & Wilkins, Baltimore, 1979. 158 pp., illus., index, \$10.95.

This book is intended to serve as an introduction to gastrointestinal physiology for beginning medical and graduate students. The authors have placed a premium on essentials and brevity stressing physiological mechanisms and highlighting essential concepts by illustrations. Clinical examples have been added and the topics include gastrointestinal functions and secretions, and absorption with special emphasis on membrane transport and gastrointestinal circulation.

Although the intentions of the authors are laudable and there is probably a need for such a book, both for medical and graduate students and for review by residents and fellows being trained in gastroenterology, this book is not adequate. The general approach is superficial and the mixture of clinical and basic information does not provide the explanations necessary to understand this aspect of physiology. Despite the attempts of the authors, the illustrations are not clear and simple but in general are not good enough for teachers to use as teaching tools or for students to gain adequate knowledge by reviewing independently. The general writing is not clear and there are areas of poor grammar. The production of such monographs to cover succinctly but inclusive of contemporary important basic advances is competitive and there are other books already on the market which seem to fill the bill better than this one.

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*Neurophysiology of Postural Mechanisms, second edition.* T.D.M. Roberts. Butterworths, Boston 1978. 415+ xv pp., illus., hardbound, \$74.50.

The second edition of this text appears 10 years after the first. The thrust of the text concerns the influences of vestibular and cerebellar systems on the mechanisms of posture and locomotion. The author presents the ideas in a logical sequence beginning with cellular elements necessary to understand impulse generation, propagation, transmission and ultimately muscle fiber shortening. Part two deals with the regulatory mechanisms controlling tone and power and has an excellent exposition of bipedal and quadripedal gait. Part three is concerned with the vestibular and other balance mechanisms and part four deals with other central nervous influences on posture and locomotion. The references are organized in an unusual fashion, being given in two appendicies, one of which is organized by chapter and the other by complete citations to the literature.

As is usual with texts originating in the British Isles the writing is literate and easy to follow. The author has developed the information in each chapter beginning with simple concepts and deriving more complex ideas from these in a fashion that would be helpful to students at the intermediate level of physiologic expertise.

The text is designed for an intermediate level course in physiology and could well serve as a reference for additional reading for students interested in posture and locomotion. It will be particularly useful in physiology courses designed for physiatrists and physiotherapists. It is unfortunate the price is so high. The organization of references, while removing their "distraction" from the chapters, has the defect of failing to introduce the student to the concept of documentation in scientific exposition.

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# PULMONARY CROSSWORD PUZZLE

by barbara graham



#### ACROSS

- 2. Englishman who did important experiments on measuring blood pressure, velocity of flow & capacity of different vessels
- self-esteem (plural)
- 8. first to see blood flowing through pulmonary capillaries
- 10. Illinois (abbr.)
- 11. Great Britain (abbr.)
- 12. the organ of voice production
- 15. a condition where lots of blood is temporarily removed from general circulation
- 17. Latin for site
- 18. prefix meaning liver
- 21. a black cuckoo
- 22. Georgia (abbr.)
- 23. big
- 24. blood constituent needed for excitation contraction of muscles (abbr.)
- 25. symbol for nickel
- 26. prefix for 10-18
- 27. Latin for salt
- 28. the small, living & active basis of all plant & animal organization
- 29. having a frequency within the audibility range of the human ear
- 30. the first light source used in combating bilirubinemia in newborns
- 31. indicating an alternative32. the time prior to Christ
- 33. may or may not be
- 35. normal inspired volume
- 38. an organ used for gas exchange underwater
- 39, what an individual is when he has developed changes in structure which are not due to disease & associated with increased probability of death
- 42. a Hawaiian food made of taro root
- 43. to hit with a sharp slapping blow
- 45. the part of the psyche which is completely unconscious
- 46. a house plant of the arum family (Zantedeschia aethiopica)
- 48. bicarbonate
- 54. blood oxygenation is determined by what ratio
- 56. phospholipid molecule which lowers surface tension
- 62. our blood has a \_\_\_\_\_ of about 7.39 63. increases in obstructive diseases
- 65. that part of the lung where molecules move by diffusion
- 67. a Canaanite & Phoenician local deity
- 68. resting lung volume (abbr.)
- 69. House Surgeon (abbr.)
- 72. King of Troy during the Trojan War
- 73. Obstetrics (abbr.)
- 74. body electrolyte actively transported out of the cell (abbr.)
- 75. a function word indicating entry, insertion or inclusion 76. to \_\_\_\_\_\_ the lower airways is to increase the closing volume
- 79. increases during hyperventilation
- 81. medical school located in Norfolk, VA (abbr.)
- 84. in the same place
- 86. boy's name
- 87. instrument used to measure lung volumes
- 91. often characteristic of persons with chronic obstructive lung diease
- 93. organ most applicable to this crossword puzzle
- 94. symbol for selenium
- 95. meaning, in the event that
- 96. another gas beside Helium which can be used to measure Functional Residual Capacity (abbr.)
- 97 Egyptian sun-god & chief deity
- 98. one of two words used in front of singular nouns
- 99 a vallev
- 100. hyperventiation will make blood .
- 101. that part of the lung not participating in gas exchange (two words) 103. a S.W. Asian & N. African musical instrument

- 104. a very small infesting bug
  105. change in volume over change in pressure
  106. substance put in lighter than-air ship (abbr.)
- 107. occurs during respiratory depression
- 108. gas used to measure vital capacity
- 109. to ingest, chew & swallow
- 112. gas which does not stimulate the central chemoreceptors
- 114. gas used to measure diffusion capacity (abbr.)
- 116. the \_\_\_\_ \_ cola
- 118. blood test needed to assess respiratory statis (abbr.)
- 120. 16th century Spaniard who described pulmonary circulation
- 122. PCO2 will increase when patient is \_ ventilated
- 125. name of lung volume at end of maximum expiration
- 126. to breath out

# DOWN

- 1. a condition where 50% < mortality < 100%
- 3. an impaired ventilatory exchange of O2 and CO2
- 4. the female sexual cell or gamete
- 6. festivity
- shin bone
- 9. the symbol for " Quick Silver"
- 13. bodily function required of all surviving medical students
- 14. a prickly or stinging plant
- 16. having equal angles
- 19. to act out
- 20. that part of circulation where gas exchange occurs
- 26. gas used as a filler for electric bulbs (abbr.)
- 27. second (abbr.)
- 28. street cleaners of the lung
- 29. procedure necessary for maintaining a clear airway in patients on respirators
- 34 determined by lung static recoil & upstream resistance near residual volume
- 36. vessel distal to inferior vena cava
- 37. deciliter (abbr.)
- 38. general practitioner (abbr.)
- 40. "the house," in Spanish
- 41. a condition caused by withdrawal of a drug (abbr.)
- 43. Latin word for for sun

men (abbr.)

50. a clenched hand

to do" 54.

Asia

66. swine fat

75. to be

70. small lung units

77. misery, affliction (archaic)

82. projections found in intestines

83. Marine Corps League (abbr.)

85. octopuses use it in defense

88. steep hill with level top

94. symbol for silicon

101. decimeter (abbr.)

110. of high rank or quality

119. to turn to the right side

115. what ruminating animals chew

113. symbol for niobium

121. symbol for titanium

106. coxa

45

79. a state of tranquillity

80. shore patrol (abbr.)

51. symbol for einsteinium

52. room temperature (abbr.)

58. increases in respiratory acidosis

60. a wing-like anatomic process or part

64. stands for "in the year of our Lord"

44. the part of the lung that has the highest blood flow

49. this hormone stimulates the Graafian follicles of the ovary in

53. something extremely fashionable can be termed "the

59. an ethnic group associated with valley paddy-rice culture in S.E.

61. an offensive football formation: fullback behind center & quarter-

78. liquid secreted from blood into lateral ventricles of brain (abbr.)

women & is partially responsible for inducing spermatogenesis in

thing

45. the relative intelligence of a person (abbr.)

\_ is highest at the apex of the lung

57. what sphygmomanometers measure (abbr.)

back with halfbacks on either side (abbr.)

81. most common cause of an increase in ventilation

62. is almost linearly related to CO2 content

71. the body's main form of energy (abbr.)

89. longest part of conductive passageway

102. the 2nd highest part in 4-part harmony

104. extinct flightless ratite bird of New Zealand

111. a unit of pressure equal to 1/760 of an atmosphere

123. one that formerly held a specified postition or place 124. this factor in your blood is either positive or negative

117. a metal fitting that electrical wires are soldered or connected to

90. blood/gas \_\_\_\_\_ increases in pulmonary edema 92. used as a mild oath (archaic)

55. components of a \_\_\_\_\_ arc pH, PCO<sub>2</sub> & PO<sub>2</sub>

47. what the operating room is commonly called 48. the air conducting passage without cartilage

# PULMONARY CROSSWORD PUZZLE Barbara Graham

The Pulmonary Crossword Puzzle was composed early last year while I was employed as a research technician in the Physiology Department at Eastern Virginia Medical School in Norfolk. The puzzle was designed for first year medical students studying Respiratory Physiology under Dr. Peter A. Koen. Dr. Koen provided a prize for the first student to complete it correctly.

I am now employed in the Department of Physiology at the Medical College of Virginia in Richmond under Dr. Roland N. Pittman. The puzzle will be given to the medical students here also.

