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DEMONSTRATIONS

A special muscle layer in the intestinal muscular coat

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A thin layer of smooth muscle, the cells of which are smaller and more electron-dense than the ordinary muscle cells, is present in the innermost part of the circular muscle layer of the guinea-pig ileum (Gabella, 1972) and the dog duodenum (Duchon, Henderson & Daniel, 1973). This structure has now been found also in the mouse, rat, dog, rabbit, sheep and cat ileum. In the guinea-pig ileum fixed in physiological distension these small cells measure about 11·7 μm^2 in their nucleated portions, are up to 1 mm long and have an average surface-to-volume ratio of 2·8 (2·8 μm^2 of cell surface for every μm^3 of cell volume; the corresponding values for the ordinary muscle cells of the circular layer are 18·6 μm^2, 750 μm and 1·4). These small cells have long, thin processes which surround the nerve bundles and sometimes make a nexus with the ordinary muscle cells. These small muscle cells display numerous mitochondria, sarcoplasmic reticulum, caveolae and myofilaments, and are surrounded by numerous collagen fibrils. Two thirds of the intramuscular vesiculated axons are situated near the small muscle cells, in the area between them and the bulk of the circular layer. Unlike the rest of the smooth muscle cells the small ones show some close contacts with nerve boutons, some of which contain cored vesicles, some only clear ones. In fluorescence microscopy, adrenergic fibres are seen in this part of the circular layer.

No evidence on the function of these small muscle cells is yet available. Since they are situated in the central part of the intestinal wall, immediately underneath the submucosa, they may be affected by pressure changes in the lumen before any mechanical changes occur in the main muscle coats. The fact that they receive a major part of the innervation suggests that they are important in nervous control. Perhaps the motor innervation from intramural and prevertebral ganglia sets them at a

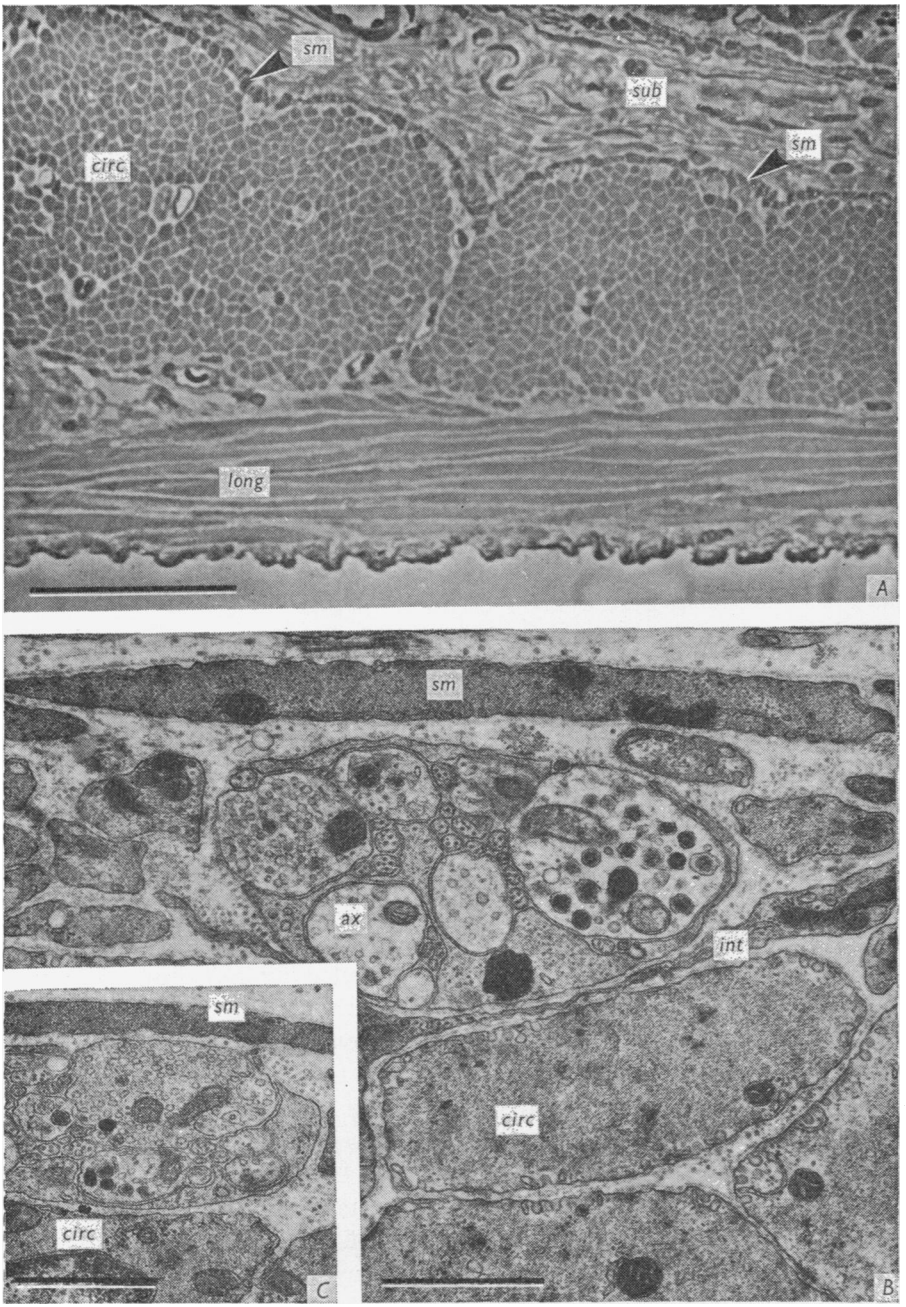

Fig. 1. *A*. Unstained section of rabbit ileum in phase contrast. *B*. Electron micrograph of guinea-pig ileum circular muscle. Between the ordinary and the small muscle cells is a nerve bundle with vesiculated axons. *C*. Same as *B*, with a vesicle-containing axon close to a small muscle cell. *long*, longitudinal muscle; *circ*, bulk of the circular muscle; *sm*, small muscle cells; *int*, interstitial cell; *ax*, axon; *sub*, submucosa. Scale: *A*, 25 μm; *B* and *C*, 1 μm.

certain level of contraction and therefore of responsiveness to mechanical stretch. Physiological experiments should clarify whether this layer of smooth muscle cells has a special function of initially detecting mechanical deformation and somehow, perhaps through afferent fibres, uses this information to cause a subsequent contraction of the bulk of the circular layer.

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Automatic analysis of stepping movements in cats by means of a television system and a digital computer

BY E. H. FURNÉE, J. M. HALBERTSMA, G. KLUNDER, S. MILLER, K. J. NIEUKERKE, J. VAN DER BURG and F. G. A. VAN DER MECHÉ. *Department of Applied Physics, University of Technology, Delft, and Department of Anatomy, Erasmus University, Rotterdam.*

Movements at four limb joints in the cat (shoulder, elbow, hip and knee) have been recorded by sampling the positions of eight points on the fore- and hind-limb of the same side. The technique of video to digital conversion described by Furnée (1967) permitted automatic analysis of movements in man by means of a television system scanning the positions of small light bulbs. In the present investigation light bulbs have been exchanged for disks of white paper (5·5 mm diam.) glued to the skin of the cat over the various bony landmarks around each joint. Under conditions of ultra-violet light, pulsed at the television scanning rate of 60 frames per sec, the paper disks could be recorded by the television camera as white dots against a black background. During the scanning process the positions of the dots are converted into an X co-ordinate by a time interval counter and into a Y co-ordinate by a line counter, giving an X, Y resolution of $9+9$ bits. For reasons of convenience these co-ordinates were stored on digital magnetic tape for subsequent analysis by a small computer system (8K memory, graphics display and disk storage).

Computer programmes with several interactive features have been written to enable an analysis of the variations of joint angles of the cats during stepping at different fixed velocities on a treadmill (0·7 to 4·0 m. sec^{-1}). The main aims of the analysis have been to obtain (1) superimposed curves of joint angles for a number of successive steps (see Fig. 1), (2) averaged values for these curves, and (3) histograms of time intervals

between closely coupled movements. The data obtained with these techniques have provided further support for the hypothesis (Miller & van der Burg, 1973) that the coordination of hind-limb and forelimb movements is largely independent of the velocity (above about 1·4 m.sec^{-1}) and the type of the gait.

This work was partly supported by FUNGO (Dutch Organization for Fundamental Research in Medicine): project no. WMRG 13–31–12.

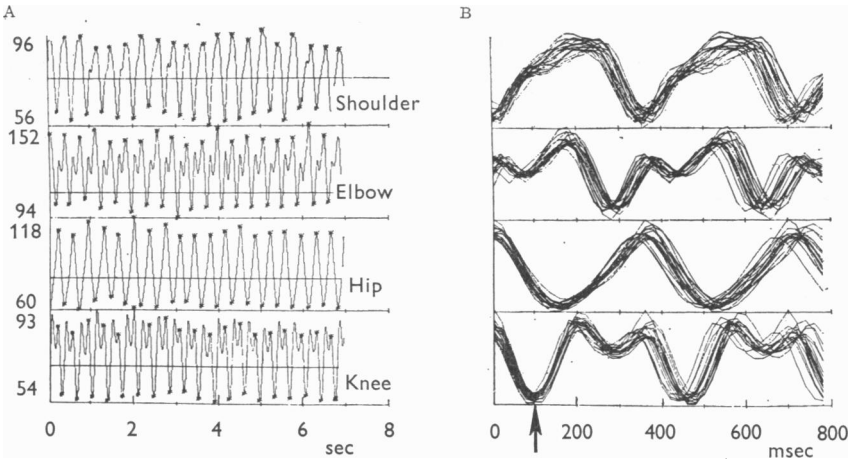

Fig. 1. Variation of angles at shoulder, elbow, hip and knee of limbs of same side during stepping on treadmill at 2·0 m.sec^{-1}. Upward excursion indicates extension, downward flexion. Numbers in ordinate indicate extremes of angles in degrees. *A*, 19 successive steps. Stars mark the turning points of flexion and extension. Horizontal lines drawn through the traces represent windows set by the operator during the recognition procedure for the turning points. *B*, the same steps superimposed. The onset of extension of the knee joint (arrow) has been used as the starting point of each step.

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Pathways for bulk outflow of aqueous humour and cerebrospinal fluid

BY BRENDA J. TRIPATHI and R. C. TRIPATHI. *Institute of Ophthalmology, University of London, Judd Street, London WC1H 9QS*

It is generally agreed that aqueous humour of the eye and cerebrospinal fluid of the brain are continuously formed and therefore must necessarily

drain away; the precise mechanism of their drainage has, however, been a subject of intensive investigation and lively debate for well over a century.

In the primate eye, aqueous humour is secreted by the ciliary processes and flows via the pupil into the anterior chamber and finally into Schlemm's canal and then into the intra- and epi-scleral plexus of veins. Our ultrastructural studies reveal that the endothelial lining of Schlemm's canal is a continuous membrane, the intercellular spaces being sealed by tight junctions and offering a barrier to larger molecules of the aqueous humour. Analysis of normotensive eyes and eyes experimentally perfused with particulate matter of colloidal dimension or autogeneous whole blood reveals that the bulk outflow of the aqueous humour takes place down a pressure gradient via temporary vacuolar transcellular channels, formed by gradually enlarging membranous depressions on the basal aspect of the endothelial cell surface which eventually open on the apical aspect. A cyclical process is proposed to be involved in the creation of vacuolar transcellular channels (Tripathi, 1971). It is further suggested that such channels, in providing the requisite number of pores at any one time, are a controlling factor in the outflow of aqueous humour and in the maintenance of normal intraocular pressure.

Our electron microscopical studies of normal and experimentally perfused eyes from a wide variety of vertebrates (carnivores, rodents, ungulates, birds, reptiles, amphibians and fishes) have further shown that although there are gross morphological variations in the configurations of the angle of the anterior chamber, they all have an angular aqueous plexus or sinus (analogous to Schlemm's canal in primate eyes) and that the bulk flow of aqueous humour across the endothelial barrier of these channels takes place via vacuolar transcellular channels, a situation exactly comparable to that seen in primate eyes (Tripathi & Tripathi, 1974*a*).

The parallelism between the physiology of cerebrospinal fluid and aqueous humour has often been remarked upon especially by Davson who recently advocated that our findings in the eye could also be applicable to the drainage of c.s.f. and if so could go far to resolve the conflict amongst morphologists and physiologists (Davson, 1972). Our studies have shown for the first time that the mesothelial lining of the arachnoid mater adjacent to the superior sagittal sinus is a continuous membrane, and the bulk outflow of c.s.f. takes place down a pressure gradient via vacuolar transcellular channels similar to that shown for the aqueous humour (Tripathi, 1973; Tripathi & Tripathi, 1974*b*).

This demonstration illustrates, therefore, an entirely new concept involving a fundamental biological process, hitherto unknown, for the bulk

outflow of both aqueous humour and cerebrospinal fluid from the anatomically closed cavities of the anterior chamber of the eye and the subarachnoid space of the brain, respectively.

We wish to thank Professor N. Ashton, F.R.S. and Dr H. Davson for their encouragement, and the M.R.C. for financial support.

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A technique for catheterization of the rabbit's superior sagittal sinus

BY H. DAVSON, J. G. HOLLINGSWORTH and J. G. MCCOMB. *Department of Physiology, University College London, London WC1E 6BT*

Sampling from the superior sagittal sinus (SSS) is needed in some studies of the blood–brain barrier. Rodnight & Tresize (1957) placed a trephine-hole over the torcular, which was then fitted with a catheter-containing plug through which blood samples were withdrawn after incising the vessel. Pappenheimer & Setchell (1973), using this technique, found it necessary to make bilateral 1 cm parietal burr-holes to accommodate the brain swelling that often caused cessation of blood flow. In applying this technique to the rabbit we found that ventriculocisternal perfusion with artificial cerebrospinal fluid was precluded, owing to bleeding into the perfusion fluid; hence we have developed a technique for cannulation of the SSS.

The dorsal aspect of the skull is exposed following incision of the skin and elevation of the periosteum. Two 0·5 cm triphine holes are made, one on each side of the mid line at the coronal suture. The dura is carefully separated from the overlying bone, which is then removed. It is best to start well anteriorly, as the dura is less adherent in this region. The craniectomy is continued posteriorly until the SSS is satisfactorily exposed. This may include dissection to the torcular as the size of the SSS showed considerable variability. Increased difficulty in bone removal occurs as the torcular is approached, as the bone becomes more vascular and the dura more firmly attached.

With a No. 26 hypodermic needle, a hole is made in the SSS, and through this a plastic catheter is introduced. Bleeding at the site of catheter entry has not been a problem. With the catheter in place, blood

samples can be withdrawn at intervals, or continuously, for a number of hours. Brain swelling has been a very rare complication. Ventriculo-cisternal perfusion can be carried out, bleeding ino the perfusion fluid being very rare.

^{131}I was perfused through the ventriculo-cisternal system, and its absorption by the choroid plexuses and capillaries of the brain was examined by measuring the activity in the SSS-blood above that in the arterial blood. Inhibition of absorption was brought about with perchlorate. The

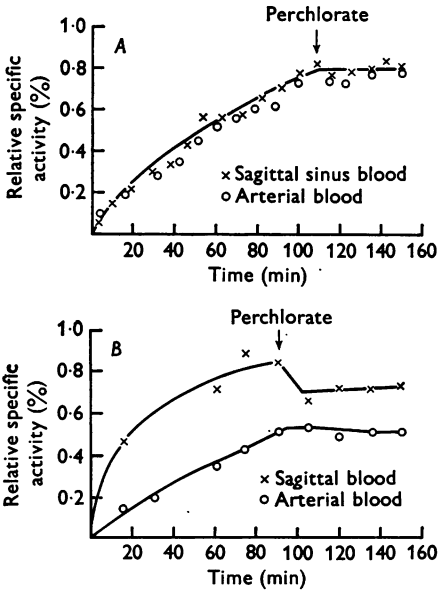

Fig. 1. Appearance of ^{131}I, absorbed from ventriculocisternal perfusion fluid, in superior sagittal sinus (SSS) and arterial blood. In *B* the choroid plexuses apparently contributed to the blood collected in the SSS; in *A*, apparently not.

results were variable; frequently, as in Fig. 1*A*, there was little or no difference in concentration in SSS- and arterial bloods; in others, as in Fig. 1*B*, the concentration in SSS-blood was much the higher. If the absorption of ^{131}I from the perfusion fluid is almost entirely carried out by the choroid plexuses, rather than the brain capillaries, the different results can be attributed to success or failure in collecting choroid-plexus blood in that withdrawn from the SSS. Preparations of the brain injected with coloured Latex through the SSS were shown, confirming the possibility that, by gentle removal of blood from the SSS, the blood draining the choroid plexuses might well escape downstream from the withdrawal site.

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Heat losses from the moving limbs in running: the 'pendulum' effect

BY R. P. CLARK, B. J. MULLAN, L. G. C. E. PUGH and N. TOY. *Laboratory for Field Physiology, National Institute for Medical Research (Hampstead Laboratories), London, N.W. 3*

In studies on an athlete running at 4·5 m/s outdoors, the coefficient of heat transfer from the body surface to the environment by convection was estimated as being 29·8 W/cm² °C (range 28·6–30·9 W/m² °C). The corresponding value for a standing subject in an air stream of 4·5 m/s is 17·6 W/m² °C (Kerslake, 1972).

An explanation of these findings is thought to be connected with the extra velocity of the limbs relative to the trunk due to their 'pendulum' motion.

This has been confirmed in the present experiments which demonstrate a mechanism by which the local convective heat transfer coefficient can be increased by at least a factor of 2.

The local heat transfer distribution was measured around the thigh of a subject running on a treadmill in calm air and in the presence of a wind of 4·5 m/s using surface plate calorimeters (Toy & Cox, 1973). The velocities of the thigh and leg relative to the trunk were estimated from a frame analysis of a ciné film of the runner.

The convective heat transfer coefficient around the thigh when the subject ran in 'still' air (the thigh having a motion similar to that of a swinging pendulum) was 21·8 W/m²°C. This is markedly greater than for a stationary leg in an air stream having a velocity equal to the average speed of the swinging leg. During running at 4·5 m/s in the presence of a wind the coefficient increased to 53·8 W/m²°C, which is more than double the value expected from a stationary heated cylinder in a wind of the same velocity. The extra heat loss due to the wind appears to be additive with the heat loss from the swinging leg in the absence of a wind.

The flow pattern around a heated vertical cylinder in an air stream is well understood. There is a separation of the flow at some 90° to the front leading edge with an attendant low value for the convective coefficient. Further around the cylinder, in the wake of the flow, the value of the coefficient rises again.

The air flow pattern for a swinging heated cylinder in still air has not previously been considered, but clearly a forced convective pattern is alternately established and reversed during each excursion of the cylinder. An approach to this problem was made by Schlieren photography of the flow patterns around a swinging and translating heated cylinder. A film of these results was shown.

During running at 4·5 m/s in the presence of wind of equal velocity a heat loss of 63 watts was obtained for the whole thigh. Heat loss from the stationary thigh in the presence of wind was not measured directly, but an estimate was made from values obtained in calm air and corrected to a wind velocity of 4·5 m/s. The value found was 28 watts.

Estimates of the mean whole body convection coefficient for the running subject using the above values for the moving limbs and a value of 17·6 W/m² °C for the trunk yield a mean value of 30·3 W/m² °C.

It can be inferred that the evaporative coefficient would also increase because of the 'pendulum' effect. However, in the runner, even at sweat rates of 1·5–1·9 l./h, the evaporative coefficient was lower than the value cited by Kerslake, the respective values being 223 (range 161–236) W/m² kPa and 263 W/m² kPa for an air flow of 4·5 m/s. An explanation, suggested by observation, appeared to be that even when sweat was running off the face and trunk, the lower limbs were incompletely wet, so that the evaporative capacity of the air flowing over the limbs was not fully taken up. This is of practical importance to the marathon runner who needs to sponge his thighs, and not his trunk, to cool himself.

We are indebted to J. Brotherhood, who acted as subject.

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Compliance measurement in single capillaries of the cat mesentery

BY GERALDINE CLOUGH,* P. A. FRASER and L. H. SMAJE, *Department of Physiology, University College London, Gower Street, London WC1E 6BT*

Capillary walls appear to be very rigid. Even with increases of pressure of 200 mmHg in intravascular pressure no changes of capillary diameter are resolvable by light microscopy in the rat meso-appendix preparation (Baez, Lamport & Baez, 1960). It has been suggested that

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this apparent rigidity is due to the elastic properties of the capillary wall (Burton, 1965) or that the surrounding gel, which is relatively incompressible, provides the necessary support (Fung, Zweifach & Intaglietta, 1966). In order to provide data to help elucidate this problem we have measured capillary compliance in the cat mesentery by a micro-occlusion technique.

When single capillaries are occluded with a glass microprobe red cells move toward the point of occlusion as fluid is filtered from the vessel (Smaje & Verrinder, 1972). The red cell movement is not smooth; it oscillates with the changes in arteriolar pressure. This oscillation could be due to alternate filtration and re-absorption of tissue fluid and Intaglietta, Richardson & Tomkins (1971) have presented evidence for this hypothesis from an analysis of pressure–velocity profiles in the microcirculation.

If this is so then the filtration coefficient calculated from the mean red cell movement (Smaje & Verrinder, 1972) can be used to estimate the pulsatile pressure required to produce the oscillatory red cell motion observed. In different vessels the pulsatile pressure predicted varies from 30–80 mmHg, but we have shown by direct micropuncture that the pulse pressure is about ten times less than this. (The frequency response of the pressure-measuring system was about 25 Hz.)

An alternative explanation for the oscillation is that the capillary distends slightly with systole. Any changes in capillary radius would appear as cell movement in the occluded vessel with an amplification factor of approximately $2l/r$ where l is the distance between the cell and the microprobe and r is the capillary radius. In our experiments on the cat mesentery this factor was usually about 100; thus a typical red cell oscillation of 10 μm at a distance of 200 μm from the microprobe in a capillary of 8 μm radius would indicate a change in radius of about 0·1 μm. A change of this order would not be detected by normal *in vivo* microscopy.

From our estimates of capillary pressure and distension it appears that if the wall is supported entirely by a basement membrane 20 nM thick then the Young's modulus of the latter would have to be about 10^7 N.m^{-2}. This is within the range quoted for collagen of the arterial wall (10^7–10^8 N.m^{-2}; Bergel, 1961).

This work was carried out with the aid of a grant from the British Heart Foundation.

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Apparatus for simple experiments in electrophysiology

BY B. R. JEWELL and G. L. READ. *Department of Physiology, University College London, Gower Street, London, WC1E 6BT*

This apparatus was designed for elementary class experiments in electrophysiology (e.g. investigation of the action potential of frog sciatic nerve). Its particular virtues are that it is compact, cheap and robust. Six of these units have been in almost daily use in our department for the past two years, and they have proved satisfactory in every respect.

Display facilities are provided by a single beam oscilloscope (Telequipment S54AR), which has a maximum sensitivity of 10 mV/cm. The rack-mounted version is used and the other units are carried on a small sub-frame that tilts the control panel upwards for the convenience of the user. Additional amplification ($\times$ 100) is provided by a single-sided preamplifier, which has a built-in calibrator giving a square wave output of 5 mV at 1 kHz. The FET input stage has an input impedance of at least 100 MΩ, and the preamplifier has a nominal bandwidth of 10 Hz to 10 kHz. The stimulator unit is of simple design and makes use of integrated circuits. It has single shot and free running (1–10 Hz and 10–100 Hz) modes of operation, and it provides two identical output pulses, 50 μs in duration, which are adjustable in strength over the range 0–1·5 V or 0–15 V. The second pulse occurs after an adjustable delay (0·2–3 ms or 2–30 ms) or it can be switched off. Independent control of the strength of the second stimulus was omitted because it is not essential for elementary class experiments.

The sub-units are constructed in modular form for replacement servicing, and power for them is provided by a $\pm$ 15 V module, which has about 75 mA to spare for driving auxiliary equipment. The total cost of the oscilloscope and the components required for the subunits is (at present) less that £200.

A class experiment on the ankle jerk and Hoffmann reflexes using the LINC-8

BY J. E. PASCOE and G. L. READ. *Department of Physiology, University College London, Gower Street, London WC1E 6BT*

It is well known that tendon jerks can frequently be reinforced by Jendrassik's manoeuvre. However the Hoffmann reflex is less frequently

affected, and when it is the relative increase in size is quite small, requiring statistical treatment to show it convincingly. We have used the ankle jerk and Hoffmann reflex for many years as a class experiment, using the action potential of the triceps surea as a measure of the reflex. As a class experiment it suffers from the disadvantages attendant upon the need to photograph the oscilloscope traces. All too often the students left behind their wet records to dry, and never looked at them again.

The LINC-8 has been programmed so that it can be used remotely on-line from the classroom, and with all its output via its oscilloscope. When a group of students are ready, their oscilloscope is switched so that it gives a similar display to that of the computer (Furness, 1974, this meeting). The display can be cleared from the classroom, and the computer then waits for a pulse from the tendon tapper or from the stimulator in the case of the Hoffmann reflex. On receipt of the pulse the computer digitizes and stores the potential led off from the triceps surae. It is then displayed automatically on the students' oscilloscope. The subject holds a spring contact in one hand so that when the fists are clenched in Jendrasski's manoeuvre the computer is informed and the letter 'R' is displayed with the digitized reflex. The students have the option to erase this stored record or to transfer it to magnetic tape. The data may only be stored once, and it is uniquely labelled so avoiding the confusion that seems inevitable when using photographic records.

When say six reinforced and six unreinforced reflexes have been stored, the students can switch to the measure mode. In this the stored records can be called back one at a time and displayed together with horizontal cursors, the positions of which can be adjusted from the classroom. In this way the amplitudes of the reflex responses may be measured remotely and stored in the computer. At any time the students may see what measurements they have made displayed as figures in two columns, one for the control and the other for the reinforced reflexes. When the reflexes have been measured, the students can switch to the computer mode. The oscilloscope then displays the control mean, the reinforced mean, the difference between these means, each with its standard error, the value of t and the number of degrees of freedom. The students are supplied with tables of t, and it is at this stage that any deficiencies in their knowledge of statistics becomes apparent.

The experiment is wired up for three groups of students in the classroom, and each group can be switched to the computer by the demonstrator. The computer is dedicated to one group of students at a time, but once they are set up for recording the experiment takes only 15–20 min to complete.

The procedure is applicable to many experiments in which until now

photographic recording has been essential. By avoiding the delay of photography, the experiment, including measurement and statistical treatment is completed in the classroom. This produces more impact upon the students, and is more satisfying for the teacher.

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An adaptive task for the assessment of skilled movement

BY G. D. DAWSON and I. PARKER.* *Department of Physiology, University College London, Gower Street, London WC1E 6BT*

Recently a game has appeared in public bars consisting of a simulation, on a cathode ray tube, of table tennis. A spot of light moves across the screen and 'bounces' off the edges. Each player can control by a knob the position of a line at one side of the screen representing a bat. If he intercepts the 'ball' it bounces back; if he fails to do so his opponent's score is incremented.

This type of game can be made simply into a useful tool. A LINC-8 computer has been programmed to play the game, not only between two players, but between one player and itself. In the second case the computer will always win as there are no problems of perception, prediction, initiation or execution of the correct responses. However if the computer is handicapped in some way the handicap may be adjusted so that on the average the computer will maintain the same score as the subject.

The computer may be programmed to adjust its own handicap continuously to maintain the scores on the average equal, or with any specified relation between them. The magnitude of the handicap then becomes a continuous measure of the subject's performance in this rather complex task. After a specified time the change in the handicap with time may be displayed as a graph, or the figures stored for analysis.

Skilled movements may fail because of faulty perception or analysis of the situation, failure to decide on the correct response, delay in initiating movement and limited velocity or inaccuracy of the movement. Any of these failures may be simulated in the computer. How far it will be possible to find which type of handicap, or combination of them, most easily matches a patient's failure in any particular type of disorder of movement remains to be seen.

Adaptive tracking tasks have also been used for studying the effects of drugs on motor performance (Borland & Nicholson, 1974).

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The particular task demonstrated is one which gives a high degree of interest and motivation for the subject. It will be demonstrated with a simple limitation of the velocity of movement as the handicap.

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Use of a laboratory oscilloscope for the display of local signals, or output from a remote computer

BY P. FURNESS. *Department of Physiology, University College London, Gower Street, London WC1E 6BT*

When a remote computer is used connected to an experiment in a laboratory, some means may be required for repeating the computer output near the experiment. Where the output is displayed on a cathode ray tube, as it may be with a LINC-8 computer, display units are commercially available which can repeat the display at distances up to about 20 m, but they are expensive and not satisfactory beyond this distance. It has been found that it is possible to get completely satisfactory displays with an ordinary laboratory oscilloscope. Either the input to the computer from the experiment, or the output from the computer to the laboratory, may then be examined on a single oscilloscope.

An interface is required between the computer and the lines to the laboratory. From this interface the system requires 3 coaxial cables (Economy coax, 75Ω Radiospares) to the laboratory. It has been used successfully in an undergraduate class experiment over a distance of 50 m. The amplifiers for the X, Y and Z (brilliance) signals in the oscilloscope should have bandwidths greater than 100 kHz.

When the laboratory oscilloscope has outputs for its internal time base, Z modulation and Y signal preamplifier (e.g. Devices CRO) the display may be switched from the laboratory signal to the computer output. This function is carried out by the computer control unit used with the experiment. The computer interface and the control unit were demonstrated by Pascoe & Read (1974, this meeting).

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Free stylus electronic planimeter with averaging facility

By L. H. Light, A. E. Lowe and M. Rosenthal. *Bioengineering Division, Clinical Research Centre, Harrow HA1 3UJ*

A recurrent task in many fields is the reading, averaging and integrating of graphical data. Existing planimeters tend to be either very complex or require that the operator follows the curve with a stylus which is restrained by mechanical couplings.

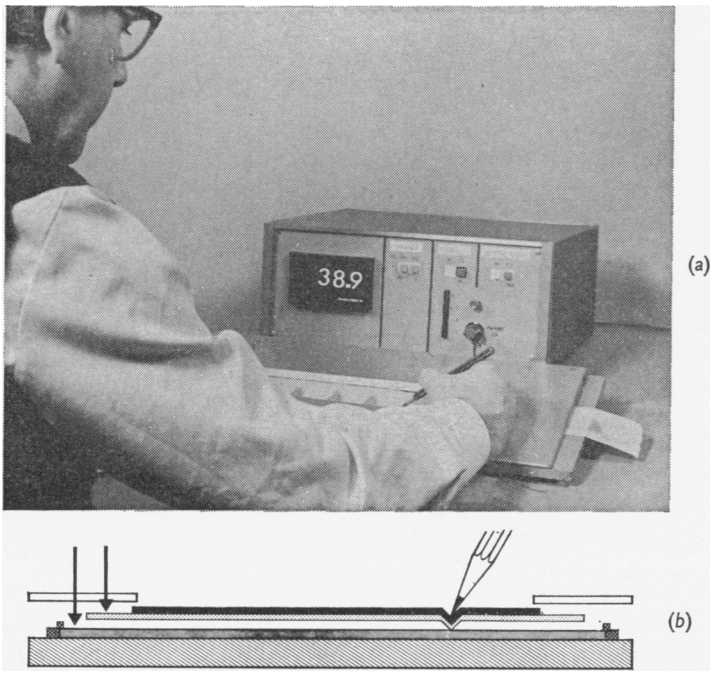

Fig. 1. (*a*) An aortic blood velocity recording is being integrated on the new planimeter to obtain an index of stroke volume. Direct indication of stroke volume and cardiac output can also be obtained if the scaling factor for the particular subject is preset on the instrument. (*b*) The stylus pressure produces a local contact between one membrane which is energized in the X or Y direction, and the other which senses the position of that contact.

In the new solution he can use a familiar implement, such as a pencil, to trace along the curve after placing it under the cover-plate of a special pad (Fig. 1 (*a*)). This incorporates two parallel resistive membranes (shown arrowed in Fig. 1 (*b*)), which are used as potential dividers in the X and Y directions (Day, Parks & Pobgee, 1972). In the present application, the voltages representing the coordinates of the local contact resulting from

stylus pressure are processed by analogue circuits to give a direct digital read-out of the area under the curve, or of its average height.

During tracing, samples of the voltage representing the height y of the curve are taken at equal increments Δx in x. The integral of these samples, representing the area $\Sigma y \Delta x$, is fed to a digital display, which can be made direct-reading in appropriate units by introducing a suitable scaling factor.

To obtain the *average height* of the curve, the circuit is switched so that the above voltage is divided by a voltage representing $\Sigma \Delta x$. If a sampling point has been missed, a warning buzzer indicates the need to retrace the last centimetre or so. (The distance retraced is not critical, as sampling will recommence at the point where contact had been lost.)

Provision has also been made for the direct read-out of spot heights and gradients (the latter with the help of a graticule).

As shown, the system is constructed to integrate or average time-dependent variables, e.g. to obtain mean aortic blood velocity from the instantaneous velocity recordings obtained by Transcutaneous Aortovelography (Light & Cross, 1972). It can, however, be modified to measure also areas within closed boundaries, such as the size of cells or organelles in electron micrographs.

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Transcutaneous comparison of blood flow velocity in the aorta and pulmonary artery of children

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A non-invasive ultrasonic Doppler technique which gives a measure of mainstream flow velocity in the transverse aorta of most subjects has previously been demonstrated (Cross & Light, 1971).

Comparisons which have been carried out between transcutaneous aortovelography (TAV) and several established techniques of measuring blood velocity and cardiac output have shown good *proportionality* in any one subject when his peak velocity and stroke volume were varied by pacing, exercise or atrial fibrillation. It did not, however, prove possible to calculate *absolute* flow values with useful accuracy from TAV and radiographic data by making the assumption that the transverse velocity profile was perfectly flat (Light, 1974).

The possibility of non-invasively following changes in flow as well as observing other haemodynamic variables, such as peak velocity, early

systolic acceleration and the duration of the ejection and pre-ejection times, opens up a number of applications for TAV in physiology and pharmacology (Light *et al.* 1974). This is now extended by the observation that it appears possible to use the same technique in children to obtain a measure of blood velocity also in the pulmonary artery from the body surface via a left intercostal space. Grossly unequal velocities in the aorta and pulmonary artery probably indicate congenital abnormalities (Fig. 1).

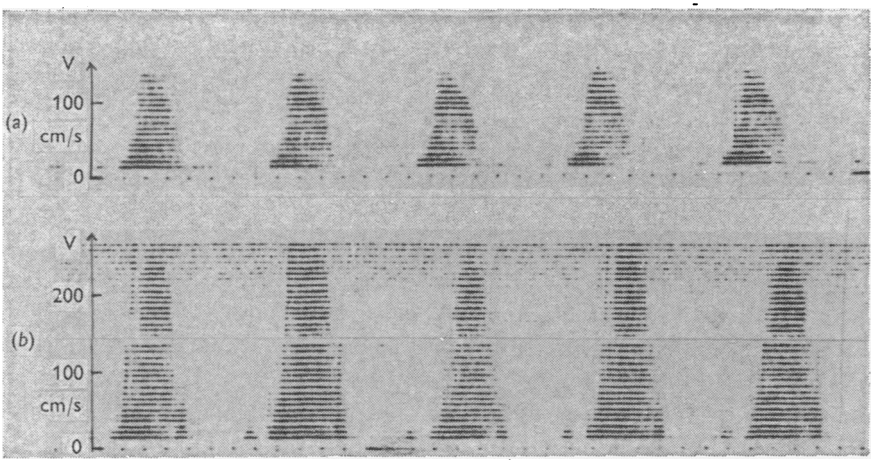

Fig. 1. Recordings of blood velocity (*a*) in the transverse aorta and (*b*) the pulmonary artery in an 11-year-old boy with atrial septal defect, obtained non-invasively via the suprasternal notch and an intercostal space respectively. The outline of the darkened area gives instantaneous blood velocity. (As the analysing span of the prototype instrument is limited, the pulmonary artery recording was assembled from a normal and an offset-zero recording.) After surgical correction, peak velocities in both vessels equalized to $\simeq$ 200 cm/s.

A convenient method of extracting indices of stroke volume and cardiac output by respectively integrating and averaging the velocity records on a novel planimeter is the subject of another demonstration (Light, Lowe & Rosenthal, 1974).

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A cost-effective electrophysiology class unit

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Physiological events, both fast and slow, are well recorded on the screen of a storage oscilloscope. The ease of inspection and erasure of the traces obtained has many advantages for teaching purposes. In the design of the present unit we have therefore accepted the relatively high cost of a dual-beam storage oscilloscope (Tektronix Type 5103N) and off-set it by choosing cheap plug-in modules which were modified in the departmental workshops. The following Tektronix modules were selected and adapted as described.

(1) *Time-base Type 5B10N* (1 μsec/div to 5 sec/div). A combined inverter and wave-shaper was added to give a 10 V negative pulse for triggering the stimulator. This pulse is brought out to a BNC socket on the time-base front panel.

(2) *Y-amplifier Type 5A23N* (10 mV/div to 10 V/div d.c. to 1·5 MHz). An additional amplifier (gain 100) was incorporated comprising an AD520J I.C. (Analog Devices Ltd.) followed by an active filter (741) 3 db down at 30 kHz. Amplifier and filter are switched in automatically when an external probe (2 × F.E.T.'s) is plugged into the 4-pin socket fitted to the front panel. The combination of the AD520J and the external probe provides a differential input of high common mode rejection ratio. Sockets on the probe input give either d.c. or a.c. coupling, the latter with a time constant of 2 sec.

(3) *Y-amplifier Type 5A24N* (50 mV/div to 1 V/div, d.c. coupled). An additional amplifier (741, gain 50) was added without switching, the input being now taken from a 5-pin socket on the front panel. Only d.c. coupling is used but a wide-range off-set voltage, variable from the front panel, is provided. An edge-wise voltmeter is fitted. This is helpful in setting up transducers. The module is intended for use with solid-state isometric force and pressure transducers and P.E. type isotonic transducers (Mercury Electronics Scotland Ltd.)

The unit incorporates a mains operated, single channel stimulator constructed to our specification by C. F. Palmer (London) Ltd. (Type RD271). Single-pulse, train or continuous operation is available in the range 0·1 Hz to 200 Hz. Variable delay to 1 sec and pulse width to 2 msec are provided. The trains are triggered manually; at all in-train frequencies the first pulse is timed by the delay setting. This facilitates composition of superimposed traces on the storage screen. An output is available for triggering the oscilloscope. Alternatively the stimulator can be triggered from the modified time base.

A reduction in equipment housing costs is achieved by mounting one oscilloscope and one stimulator back-to-back in a double sided cabinet for use by students on opposite sides of a free-standing bench. The two stimulators in one cabinet may be linked for two-pulse experiments.

For stimulation of nerves in man a separate high-voltage unit is used (Mercury Electronics Scotland Ltd). This contains a battery-operated pulse amplifier isolated from the pulse-generating stimulator by a photo-coupler giving an insulation of 10^9 ohms at 1 kV. The maximum output pulse height is 250 V at 2×10^3 ohms. The width of the output pulse is equal to that of the input pulse; but if the input pulse accidentally exceeds 200 μsec in duration and/or 10 pulses/sec a short time constant coupling combined with a small reservoir capacitor in the battery supply cuts down the output.

Thirty-two sets of apparatus have been built and have now been in use by elementary classes for one year. Details of the modifications made and costings (1972/73) are available.

COMMUNICATIONS

Electrophysiological studies of the brain of *Octopus vulgaris*

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The large amount of neuroanatomical and behavioural information available for *Octopus vulgaris* (Young, 1971) makes this animal attractive for electrophysiological investigation. Beginning with the work of Piper (1904) and Frölich (1913) on the electroretinogram in *Octopus* all electrical recordings to date from cephalopod molluscs have involved the visual system. Recently MacNichol & Love (1961) have recorded impulse activity in the optic nerves of *Loligo*. As far as is known no information exists on the electrical activity in the brain of *Octopus*. This may be due in part to the technical problems associated with immobilizing the animal. In this study the animal was immobilized with cold sea water (8° C) and by stitching to a solid frame.

As a first aim, the feasibility of extracellular micro-electrode recording was tested. Examples of responses in the optic nerves and optic lobe to flashes of light in the eye; responses in the peduncle lobe arising from mantle contraction and touching of the arms; and responses in one peduncle lobe to electrical stimulation of the opposite peduncle lobe have been obtained.

The second and principal aim was a search for a reverberating neural