Papers and Originals

Place of Vestibular Nerve Section in Ménière's Disease

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It is likely that as new approaches are introduced in the treatment of any condition which hitherto has seemed intractable the value of the older methods may be forgotten. This is especially true when the new approaches are introduced by members of another specialty. Such in this country appears to be the fate of vestibular neurotomy in the treatment of Ménière's disease, particularly in those patients who still retain useful hearing in the affected ear and who have not been relieved by medicinal therapy. Thus in an editorial article in the *B.M.J.* (29 June 1963) the neuro-surgical approach was not even mentioned when the surgical treatment of Ménière's disease was discussed. Yet in Sweden (Castellano, 1951), the United States (Ueki and Walker, 1960), and Germany (Gröschel and Wustrow, 1961) the operation still has its advocates. It therefore seems opportune to compare its merits and its hazards with those of other surgical approaches; and also to report a small personal series of cases which indicate not only that neurotomy, given the right indications, is almost invariably successful, but that useful hearing may often be preserved in the affected ear for many years.

Salient Features of Ménière's Disease

Cawthorne and his colleagues (Cawthorne, 1943, 1949, 1956, 1957a, 1957b, 1959; Cawthorne and Hewlett, 1954), as well as others (Dandy, 1928; Cairns and Brain, 1933; McKenzie, 1936; Crowe, 1938; Ueki and Walker, 1960), have given us clear descriptions of the salient features of Ménière's disease. All of them describe the disease as presenting a triad of symptoms comprising vertigo, tinnitus, and deafness in widely varying proportions. Probably, however, it should be regarded as a tetrad (Mygind and Dederding, 1934; Symonds, 1938); for headache, either occipital or generalized, intermittent or constant, also often occurs, and indeed may occasionally be so conspicuous as to lead to a suspicion of brain tumour (Symonds, personal communication, 1964). A synonymous term for Ménière's disease is "aural vertigo," and by definition, therefore, the presence of vertigo is essential for diagnosis, although one or more of the other features of the tetrad may be absent. Indeed, it is possible that the underlying pathological process of labyrinthine hydrops may cause deafness and tinnitus without vertigo. Consequently in cases labelled Ménière's disease attacks of paroxysmal vertigo associated with nausea and vomiting and with disturbances of equilibrium are usually the presenting and most demoralizing symptom, and can occur with varying grades of frequency and severity. The sensation is usually one of whirling, but sometimes it may be only a feeling of sudden linear

movement as in one of the cases reported below. The attacks usually start before the age of 50 years and occur with equal incidence in the two sexes. In over 85% of cases they are associated with evidence of unilateral disturbance of vestibular function taking the form of unilateral deafness and tinnitus. Generally the deafness and tinnitus are noted simultaneously with the first attack of vertigo, but sometimes one or both may precede the vertigo by days, months, or years. In the classical descriptions the deafness is progressive, and by the time surgical therapy is contemplated useful hearing is lost or such hearing as remains is distorted. It is said that in unoperated cases, when the deafness becomes complete, vertigo disappears unless the other ear has become involved in the meantime. However, this statement has to be qualified, because sometimes an apparently completely deaf ear may still retain sufficient function to provoke vertigo. Furthermore, the rate of progress of the disease as regards hearing varies considerably, and occasionally useful hearing may persist for many years.

This may lead to some problems of lateralization when surgery is considered. My personal experience comprises some eight patients submitted to partial acoustic (vestibular) neurotomy in this country since 1950 and summarized here, and a similar small group operated upon previously in New Zealand and not yet recorded. The most reliable index regarding which labyrinth is disturbed is unilateral tinnitus, which may reach a crescendo immediately preceding an attack, or also a more or less constant background noise which alters in quality during an attack, either by augmentation or decline. In one of the New Zealand series there was bilateral deafness, but the tinnitus was present only in the less deaf ear. This patient was submitted to a unilateral vestibular neurotomy on that side, with a good result. Tinnitus, however, was present in only six of the eight cases in the present series; in one it was completely absent, while in another it took the form of a feeling of "blocking" in the affected ear without a hallucination of sound. Deafness again is not constant, for one patient had normal audiograms, although there was unilateral tinnitus at the time of the attack. However, in all cases there was some impairment in the quantitative caloric responses of the affected vestibule as judged by the methods pioneered by Fitzgerald and Hallpike (1942).

The studies of Hallpike and Cairns (1938) and others (see Cawthorne, 1949) have shown that the underlying pathological basis of Ménière's disease is a distension or hydrops of the cochlear canal and saccule of the endolymphatic system. Presumably the hydrops at first may be intermittent and only later lead to permanent damage. It is possible that it may sometimes be both intermittent and self-limiting. The two patients studied by Hallpike and Cairns both died after intracranial section of the acoustic nerve, indicating that the operation does carry risks to life. However, such risks have probably been overemphasized.

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Surgical Approach

There have now developed two standard rational approaches to the surgical treatment of Ménière's disease when it can no longer be controlled by medication. The first of these is by destruction of the affected labyrinth by one of several methods, and the other is intracranial section of part or all of the acoustic nerve. Other operative approaches have also been tried, such as the Portmann procedure of drainage of the saccus endolymphaticus into the subarachnoid space, section of the chorda tympani nerve, and cervical sympathectomy. However, the results with these later procedures are not as promising (Cawthorne and Hewlett, 1954).

Of these two operative approaches the destruction of the labyrinth has become the more widely practised. No matter whether the destruction is by injection of alcohol into the labyrinth (Mollison, 1931), diathermy coagulation of the external semicircular canal (Day, 1943), the simple avulsion of a piece of the external canal (Cawthorne, 1943), the removal of the utricle via the oval window (Cawthorne, 1957b), or a more elaborate labyrinthectomy (Lindsay and Siedentop, 1955; Guilford, Wright, and Draper, 1957), the result appears to be the same—namely, complete deafness as well as a complete absence of vestibular function in the operated ear. The use of alcohol injections and diathermy coagulations has largely been given up because of the risk of facial-nerve paralysis; and although some hold that a more radical removal of the membranous labyrinth is needed Cawthorne's approach is the one most widely practised. In an attempt to correct its most serious demerit—namely, complete deafness—the pioneering work of Krejci (1952) in Switzerland and of James and his colleagues (1962) in this country on the use of ultrasound to destroy part of the membranous labyrinth is of great interest, because by this means it would appear that hearing is often retained. However, much equipment and technical assistance are required for these latter procedures, and this limits their availability.

The neurosurgical approach of intracranial section of the acoustic nerve, as we know it, was pioneered by Dandy (1928), although Cairns and Brain (1933), who also reported on the procedure, stated that Parry, Krause, Wallace, Ballance, and Frazier had previously tried the approach. Dandy at first divided the whole acoustic nerve completely, and even operated on some of his patients under local analgesia, reporting that the actual cutting of the nerve was without discomfort. The complete section produced total deafness in the operated ear as well as complete loss of vestibular function, although tinnitus sometimes persisted, much as it does after labyrinthectomy. The operation proved as effective as any type of labyrinthine destruction then in vogue, or even since introduced, in relieving the paroxysms of aural vertigo.

Division of the vestibular half of the acoustic nerve intracranially was pioneered by McKenzie in 1931 but not reported in detail by him until 1936, although Dandy described the procedure in 1933 after operating on a single patient a few months earlier. The advantage of section of the vestibular half of the nerve, leaving the cochlear half intact, is that it usually spares the hearing. It is thus the operation of choice in any patient who still retains useful hearing in the affected ear. Tinnitus, however, may persist, although most published accounts indicate that its frequency and gravity are usually lessened. The vestibular (caloric) responses are usually lost in the affected ear. McKenzie (1936) reported 12 cases, one of whom died of a post-operative wound infection. Five of his patients had useful hearing before operation, and three of the five retained this; of the two who failed to retain useful hearing one had had the whole acoustic nerve cut inadvertently, and the other was the fatal case. The 11 surviving patients were all relieved of vertigo.

Operative Results in the Literature

The reason why the intracranial operation has fallen into disrepute or even oblivion is that it has hazards to life which are not present with the labyrinthine approach. One of these is meningitis, as seen in McKenzie's case during the pre-antibiotic era; another is intracerebellar haemorrhage secondary to retraction of the cerebellum at operation; and indeed it was because of two such fatalities that post-mortem studies of the labyrinth in this disease became possible (Hallpike and Cairns, 1938). However, in these days of modern anaesthesia, of antibiotics, and of improvements in neurosurgical technique such as the adoption of the sitting posture for the patient during operation, the mortality of the operation in competent hands should be negligible. Indeed, as has been said before (Falconer, 1963), it is difficult by any operative procedure, otological or neurosurgical, to better the results achieved by Dandy as recorded by one of his pupils, Robert E. Green (1959). Between the years 1924 and 1946 Dandy operated on 587 patients with only two deaths, both from meningitis. His success rate was high, for he obtained relief of vertigo in over 90% of cases and improvement in a third of the remainder. In a group of 278 cases treated by vestibular neurotomy, which Green himself followed up by interview or postal correspondence, 90% were reported as relieved of vertigo, 5% as improved, and 5% were unimproved; while in 95 cases in which the hearing was examined by Green 9 had improved hearing after the partial section, 27 were unchanged, 46 were worse, and 13 were evidently deaf. Audiometric readings before and after operation were available in all these cases. According to Green, Dandy divided both acoustic nerves in 20 cases in two stages at varying intervals for bilateral Ménière's disease, and of this group 9 were relieved of vertigo, 4 were not benefited, and 7 could not be followed. Dandy himself first described bilateral sections in 1937, and later Crowe (1938) and Green (1959) reported that in these cases walking in the dark or with the eyes closed always caused staggering, while during walking or active exertion with the eyes open the vision became blurred, with objects appearing to move up and down rapidly. A bilateral operation therefore is scarcely justified.

Confirmation of the slight hazards to life connected with the operation in trained hands comes from three other published series—from Sweden, the United States, and Germany respectively—for in none of these series was there an operative death. Castellano (1951) recorded that Olivecrona, in Stockholm between 1930 and 1949, divided the acoustic nerve intracranially wholly or in its vestibular part in 253 patients, with relief of vertigo in all but eight patients, seven of whom were presumed to have bilateral disease. The follow-up period ranged from a few months to 19 years. No bilateral section was performed. In 226 of the 253 patients only the vestibular half of the nerve was divided; 43 of these became deaf in the affected ear, 26 were said to show deteriorated hearing, and in the remainder the hearing remained unchanged.

Ueki and Walker (1960), from Baltimore, reported 28 cases submitted to vestibular neurotomy as well as 2 of complete acoustic-nerve section, making 30 cases in all. Twenty-six were followed for from 1 to 10 years, and 24 of these were found to be relieved of vertigo, while the remaining two had only occasional attacks. Of 27 patients with vestibular-nerve section 14 subjectively had either unchanged or improved hearing and 13 had decreased hearing. Post-operative audiograms in 21 patients, however, showed no hearing loss in 10, slightly impaired hearing in three, a high-tone loss in six, and deafness in two. Tinnitus was said to have been relieved in six cases, but in each instance at the expense of some loss of hearing.

More recently Gröschel and Wustrow (1961) reported 26 cases of vestibular neurotomy operated on by Tönnis in

Germany between 1937 and 1959. There were difficulties in following up some of the patients. In 24 it was thought that there was adequate information, and of these one with persisting vestibular function showed a recurrence of vertigo. Twelve patients were seen again for detailed follow-up studies from one month to nine years after operation, and 11 of these were found to be free of vertigo and the remaining one was improved. This latter patient, however, still had some persisting vestibular function in the affected ear, indicating that the vestibular neurectomy had not been complete. Of these 12 patients two had improved hearing, three were unchanged, three had decreased hearing, and four were deaf on the operated side.

Personal Experience

Since December 1951 eight patients in this unit have undergone a unilateral vestibular neurectomy for Ménière's disease. The salient features of these cases are reviewed in the Table. All have been relieved of vertigo, and all have retained useful hearing on the operated side without unpleasant distortions of sound, although in five of the eight the hearing was reduced slightly following operation and in one other it has since deteriorated slightly over a period of five years. The eight cases have since been followed for from 2 to 12 years, and only one has died during this period. This patient (Case 4) died at the age of 65 years after two attacks of coronary thrombosis and some five years after operation. This small series therefore supports the claims made for the operation by previous authors. The ages of the patients ranged from 24 to 60 years, and their symptoms had begun from 2 to 16 years earlier. All had experienced episodes of sudden vertigo, but in only one was it not rotatory (Case 1). Six had experienced tinnitus, and one had not noticed any deafness, although the quantitative caloric responses in the ear exhibiting tinnitus were impaired (Case 6). One had noticed deafness only during vertiginous attacks (Case 8). Four had complained of headaches before operation; these subsequently disappeared. One of the seven still living (Case 2) underwent a bimedial leucotomy in this unit for agitated depression three years after his vestibular neurectomy, and eight years later wrote to say he was well, was leading an active life, and was not troubled by deafness. All the others are fully employed without any restrictions, and at the time of follow-up had had their audiograms checked by either Mr. T. E. (now Sir Terence) Cawthorne or Dr. A. B. Hewlett. All eight are known to have lost their caloric responses in the ear on the operated side after operation. Two cases may be cited as illustrative of the group.

Case 1

A 43-year-old man, a locomotive driver, referred by Dr. M. J. McArdle and Mr. T. E. Cawthorne, had complained of slowly progressive deafness in the left ear during the preceding two years. During that period he had experienced eight or nine attacks in which he suddenly felt himself being violently displaced to the left side, but without rotation. Each attack had lasted from three to

four hours, and during them he had been compelled to lie down. He had vomited during only two attacks. There had never been any tinnitus. Mr. Cawthorne had noted a deafness of 35 to 40 decibels in the critical frequencies in the left ear and a slight impairment of caloric responses on that side. The patient underwent a left vestibular neurectomy in October 1951. Before operation he could hear whispers at 2 ft. (0.6 m.) in the left ear and at 6 ft. (1.8 m.) in the right ear. After operation he could only hear whispers at 1 ft. (30 cm.) in the left ear. The caloric responses were now absent. Since then he has been completely relieved of vertigo. Six months later he resumed locomotive-driving, having passed the necessary medical tests. In due course he was promoted to be a locomotive inspector, and he now tests other locomotive drivers for their licences. He was also a marathon runner, but has given this up in recent years because of age. However, he still referees football matches. When seen 10½ years after operation it was noted that he tended to turn his right or sound ear towards the speaker. However, he could still hear a low voice in the left ear. Mr. Cawthorne reported that the hearing in both ears was now about 20 decibels further reduced than it was a decade earlier. Twelve years after operation he wrote saying he was well.

Case 6

A 24-year-old housewife, referred by Dr. R. Hierons and Mr. T. E. Cawthorne, had complained that since the age of 6 years she had been subject to attacks of paroxysmal vomiting lasting up to 48 hours and associated with unsteadiness of gait. During the last three years they had become more frequent, and now occurred in clusters of up to 12 attacks in a week, each attack lasting one to six hours and followed by periods of remission of from one to three months. The attacks were now associated with a sense of sudden violent rotation in a clockwise direction. Also during this same period there had been a constant hissing noise in the right ear, which rose to a crescendo shortly before a bout of attacks was due, and only when this happened was she aware of slight deafness in the right ear. To clinical tests her hearing was normal (whispers at six feet: 1.8 m.) in each ear, but Mr. Cawthorne reported that the caloric responses in the right ear were absent to water at temperatures of 30° C. and 44° C., and greatly impaired at a temperature of 20° C. Audiometry showed only a loss of 15 decibels in the affected ear.

The operation was performed in January 1959. She was discharged home two weeks later, and at that time Mr. Cawthorne reported that her audiogram was unchanged but that the right labyrinth was now inactive. Her tinnitus however persisted, but gradually became less marked. There has been no recurrence of vertigo. Eighteen months after operation she gave birth to a healthy baby. When seen 3½ years after operation her hearing had slightly diminished to whispers at 4 ft. (1.2 m.) in the right ear and was unchanged at 6 ft. (1.8 m.) in the left ear. Mr. Cawthorne confirmed a decline of about 20 to 25 decibels in the right ear. The tinnitus was still persisting, but without any periodic change. She was able, however, to do all her housework; her balance by day was perfect but in the dark was slightly "insecure." Five years after operation she reported herself as still healthy.

Operative Technique

It is but natural that details of operative technique should vary from one surgeon to another, but the essential principles

Clinical Features in Eight Cases of Unilateral Vestibular Neurectomy

Case No.	Sex and Age	Side	Pre-operative Symptoms					Follow-up Progress				
			Duration (years)	Vertigo	Tinnitus	Deafness	Headache	Duration (years)	Vertigo	Tinnitus	Deafness	Headache
1	M 43	Left	1½	Yes	No	Slight	No	12	Relieved	No	Slight increase	No
2	M 39	Left	3	"	Constant	"	Frequent	12	"	Slight	? Slight increase	Relieved
3	M 31	Left	4	"	"	"	Yes	11	"	Relieved	Unchanged	"
4	M 60	Left	2	"	Slight	"	Yes	5	"	Unchanged	"	"
5	M 36	Right	10m.	"	"	"	No	5	"	Relieved	Slight increase	No
6	F 24	Right	16	"	"	No	No	5	"	Less	"	No
7	F 32	Right	2	"	No	Slight	No	3	"	Less	"	No
8	F 47	Left	7	"	Yes	No	Yes	2	"	Relieved	"	Relieved

are the same. Many surgeons, including Dandy, have operated with the patient lying horizontal, either with the face down or lying with the sound ear down; others have operated with the patient sitting up. The sitting posture certainly facilitates exposure. Some have made a small inverted U-shaped flap of scalp and muscle over the occipital bone posterior and medial to the mastoid process, while others have made a vertical scalp and muscle-splitting incision. A bony opening about 4 cm. in diameter is made in the occipital bone with its lateral edge at the lateral sinus. Any exposed mastoid air cells are sealed with Horsley's wax, and the dura is then opened. Next, by slipping a narrow brain-retractor over the cerebellar hemisphere medially, the cisterna magna can be exposed and then ruptured, with the escape of cerebrospinal fluid. This manoeuvre allows the cerebellar hemisphere to fall away from the petrous bone, and with slight retraction the cerebello-pontine angle is opened up, exposing the ninth, tenth, and eleventh cranial nerves below, and above them the acoustic nerve at the internal auditory meatus with the facial nerve hidden immediately in front of it. The arachnoid of the lateral recess is then opened, giving access to the acoustic nerve. Occasionally a small groove may be seen running along the length of the acoustic nerve, dividing it into an upper or vestibular half and a lower or cochlear half (such a groove was seen in two of our eight cases). With a small sharp dissector the nerve is divided longitudinally into upper and lower halves at a distance of 6 to 10 mm. from the internal auditory meatus, and then the upper half is picked up on a right-angled hook and cut with a tenotome. Finally the dural opening is sutured and the muscle and scalp layers are closed.

Some mention must be made about the placing of the incision in the eighth nerve. The vestibular and cochlear halves of the acoustic nerve undergo a rotation between the internal auditory meatus and the brain stem, so that at the brain stem the vestibular half lies ventrally. At a distance of from 6 to 10 mm. from the internal auditory meatus it lies superiorly. This is the normal point at which it is sectioned, and is so illustrated by McKenzie (1936). McKenzie, however, in his text refers to cutting the "dorsal and cephalad" position of the nerve, Dandy (1933) and Ueki and Walker (1960) to cutting the "anterior" part of the nerve, and Castellano (1951) to the "cranial" as opposed to the caudal half of the nerve. Yet all these authors make the same placement, and one can only presume, therefore, that there is a confusion of anatomical terminology. With the patient in the sitting posture it is the upper half of the nerve which is divided.

For a few days after operation the patient suffers from dizziness, with a strong tendency to vomit, and has to lie still. He exhibits a nystagmus on looking to the opposite side, with its quick component to that side. Then when he is up on his feet at the end of a week or ten days he feels unsteady, with a tendency to veer on walking towards the operated side. Similar symptoms of comparable severity are of course seen after sudden unilateral labyrinthine destruction, either surgical or traumatic, or from disease. It takes some patients several weeks to adjust themselves to a sudden labyrinthine loss, and during that time patients may be reluctant to walk out of doors unaccompanied, particularly in busy streets.

The chief complication of operation has been a facial paralysis. This may appear immediately after operation, suggesting that the facial nerve has also been cut, or more commonly a few days to six weeks later (Ueki and Walker, 1960), when it is presumably due to swelling of the distal portion of the vestibular nerve compressing the facial nerve in the internal auditory meatus. It occurred 54 times in 418 of Dandy's patients contacted by Green, being transient in 37 and permanent in 17 cases (Green, 1959). It also

occurred in 16 of Olivecrona's 253 cases, but was permanent in only two. In a third case in Olivecrona's series the facial nerve was accidentally severed at operation, but in one of these it was satisfactorily repaired, with a good functional result, by a graft from the saphenous nerve held in place with fibrinogen and thrombin. Again, a transient facial paralysis occurred in three of the 30 cases reported by Ueki and Walker (1960). Fortunately it has not appeared in any of my own small series of cases of both total and partial acoustic-nerve section. This series includes, as well as the eight cases described here, 12 cases of complete acoustic-nerve section for Ménière's disease with gross hearing loss. Of these 12 cases nine were relieved of vertigo, two who had already undergone a labyrinthectomy or alcohol injection were not benefited, and one patient cannot be traced. Failure to encounter a facial paralysis after operation in this series has probably been a matter of good fortune.

Discussion

This small series of cases of vestibular neurotomy is a reminder of the claim made by those who have reported larger series that the operation is effective in patients with Ménière's disease who still retain useful hearing in the affected ear. Admittedly it has its hazards, and one of these is a risk to life which is not present in the otological approach; but statistics show that if the surgeon is experienced in the neuro-surgical approach the mortality and morbidity should be negligible. Complete section of the acoustic nerve (as when there is no useful hearing) or vestibular neurotomy (indicated when useful hearing persists) are both as effective as any of the present otological approaches in relieving vertigo, and, like them, have sometimes little effect on the tinnitus. It can of course be argued that because of the potential risk to life the operative approach of choice when there is no useful hearing is an otological one. However, if there is still useful hearing in the affected ear vestibular neurotomy offers great advantages, one of which is that the useful hearing may be preserved for many years.

Summary

Vestibular neurotomy for Ménière's disease that is resistant to medicinal therapy has largely gone out of fashion. This is mainly because otologists, to whom these patients are usually referred in the first instance, have overemphasized its complications and the risks to life. Yet an older generation of neurosurgeons operated successfully on large numbers of patients with little risk and frequent benefit. Furthermore, the operation has the advantage that usually hearing in the affected ear is preserved, while after most operations for destroying labyrinthine function there is usually complete deafness. A small series of selected cases of Ménière's disease is therefore presented to show that if there is useful hearing at the time of operation the hearing can usually be preserved, while the vertigo is relieved, and also that useful hearing may persist for many years.

I wish to thank Sir Terence Cawthorne and Dr. A. B. Hewlett, of King's College Hospital, for their help in investigating these cases, Sir Charles Symonds for his constructive criticisms, and also my former registrars, Mr. D. C. Provan and Mr. T. K. Nag, for assistance in following up the patients.

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Landmarks and Perspectives in Biochemical Research*—II

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8. Hormones

The discovery and study of substances which regulate the rates of metabolic reaction in animal tissues, the hormones, has been another most important achievement of the combination of biochemical and physiological research, and led to results of great theoretical as well as practical importance. I can do no more than mention in passing the brilliant and massive effort of many hundreds of investigators which led to the recognition of the various classes of hormones, among which the most important ones were shown to be steroids or peptides. Thanks to the astonishing progress in organic chemical methods in the fields of steroids and peptide chemistry, many hormones and their analogues have become accessible through synthesis, and, as this lecture is being written, new ingenious methods of peptide synthesis using high-polymer resins are being developed.

So far as functional biochemistry is concerned, two main problem complexes arise in the hormone field. One of them has already been referred to, their pathway of biosynthesis, and here much progress has been achieved.

In the other complex problem, that of the mode of action of hormones, progress has been slow. We really do not understand properly the action of a single hormone, or for that matter of any pharmacologically active substances, natural or synthetic, with one or two exceptions. One of the reasons why this progress in the field of the mode of action of hormones has been so slow is that for the demonstration of a hormone effect on a metabolic reaction the intact tissue is usually required, and all our extensive knowledge of enzyme reactions in cell-free systems does not therefore help us to get much further.

Altogether I have wondered for some time how significant the results obtained from studies with cell-free enzyme systems, and the various general metabolic schemes which have been suggested, really are for the living organism. They are general schemes, applicable to a variety of organisms. The recognition of the unity of the elementary basic metabolic processes in cells of all kinds, of species as different as man and bacteria, has certainly been an important concept in biochemical thinking, but it is of equal or even greater importance to stress the diversity of the living matter. To know that the tricarboxylic-

acid cycle or any other metabolic scheme is functional in liver, brain, or muscle does not really help to understand the specific

FIG. 24.—Automatic radiochromatogram scanner. The radiochromatogram, fixed to a sheet of white paper placed in the roll of a typewriter, is passed through two Geiger end-window counters by the movement of the typewriter carriage, at intervals set and determined by an electronic timer and depending on the intensity of the radiation. The pulses emanating from the area of the chromatogram exposed to the counter are transmitted to a scaler and via a discriminatory circuit to solenoids placed on the typewriter number keys. When the time of exposure is completed the solenoids of the number keys corresponding to the number of pulses collected during this time interval are actuated, and thus the number of the pulses is printed on the sheets of white paper in a position corresponding to that of the area on the radiochromatogram from which they emanated. When the exploration of one line of the radiochromatogram is completed the typewriter carriage returns to its origin, the roll of the typewriter moves the white sheet to the next line, and exploration begins again.

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