BRITISH MEDICAL JOURNAL

LONDON SATURDAY SEPTEMBER 18 1937

A STUDY OF DIET IN RELATION TO HEALTH DARK ADAPTATION AS AN INDEX OF ADEQUATE VITAMIN A INTAKE TECHNIQUE AND PRELIMINARY RESULTS

BY

J. R. MUTCH, M.D., D.O.M.S.

AND

H. D. GRIFFITH, B.A.

(Under the supervision of Sir J. B. Orr, M.D., F.R.S., Rowett Research Institute, Aberdeen)

The power that the eye has of accommodating itself to alterations in illumination is called adaptation. When an individual comes out of bright sunlight into a dimly illuminated room surrounding objects at first are invisible; as adaptation takes place first the general outline and then details of surrounding objects can be clearly seen. The time necessary for adaptation was first measured by Aubert in 1865, and since then has been studied by many observers. The sensitivity of the retina to light increases rapidly during the first ten minutes, a much slower but gradual increase taking place up to forty minutes. At the end of that time the retinal sensitivity to light has increased several thousand times. When a person leaves a darkened room and enters bright sunshine a feeling of dazzle is experienced. Rapid adaptation, however, takes place, sensitivity being enormously reduced in twenty seconds (Adams, 1929; Lythgoe, 1926). Failure of adaptation in reduced light is known as night-blindness, hemeralopia, or nyctalopia.

Association with Vitamin A

The association of night-blindness with diet is not the result of recent advances in knowledge of vitamins, but was accepted and quite extensively studied before vitamins were known or any theory could be advanced as to the nature of the relationship. Defective dark adaptation has always been common among poor people living chiefly on plant foods. Liver has been used as a cure since 1500 B.C., and was recommended for this purpose by Hippocrates (Aykroyd, 1930; Tansley, 1931). The frequent discussion of the defect during the last century shows that it must have been common throughout Europe. The peak of incidence seems to have been during the Lenten fasts in the Danubian and Eastern Mediterranean countries and in Russia. After the description by Bitot in 1863 of xerosis conjunctivae combined with hemeralopia, Netter pointed out that night-blindness can occur without xerosis, and it became evident later that the two are stages in the same disease process, night-blindness coming first (Fridericia and Holm, 1925).

Towards the end of the century Lohmann (1913) wrote: "Malnutrition is the cause of the frequent hemeralopia which occurs in poorhouses and orphan asylums. . . ." "Hemeralopia is rare in England but common in Ireland. . . ." It is clear that it must have been common in

England also, earlier in the century at least, since in the report of the medical officer of the Privy Council for 1862, where the health of the unemployed Lancashire cotton operatives is discussed, the passage occurs: "Ulceration of the cornea was inquired for but was only heard of *with special prevalence* . . ." in certain areas. It must therefore have been common at all times, and it would certainly have been preceded and accompanied by night-blindness. (See also Berry, 1886; Forbes, 1811; Snell, 1876; Spicer, 1892.) After the discovery of visual purple it was suggested that this pigment was responsible for vision in low illuminations, a theory which was supported by the demonstration of the bleaching of visual purple in light and the restoration of its colour in darkness. Finally, after the discovery of vitamin A and of its relation to xerophthalmia, experimental study of the eyes of rats showed that in vitamin A deficiency, before xerosis of the conjunctiva is obvious, the restoration of visual purple after bleaching is delayed (Fridericia and Holm, 1925; Holm, 1925). At this stage clinical hemeralopia in the rats was demonstrated by simple tests in a dimly lit room in which the rats had to jump from the corner of a table to reach a shelf of cages.

Practical Aspects

With the rapid improvement in diet in this country since the beginning of the century obvious deficiency diseases, including xerophthalmia, have become more and more uncommon, and interest centres at present on the question of the extent to which further improvements are required. Since the important dietary sources of vitamin A—milk, butter, eggs, liver, carrots, and green vegetables—are, on the whole, relatively expensive foodstuffs, it may be predicted that deficiency, if it is found at all, will be more common among the poorer people. The general conditions of life in this country are not such as to reveal deficient dark adaptation. In towns no one is called upon to do work or get about in light less than adequate even for inefficient dark vision, and even in the country such inefficiency of vision might be completely unnoticed. On the other hand, in certain occupations, particularly motor driving and aviation, efficient visual adaptation to low illuminations and to sudden changes in light intensity is of the greatest importance. A high proportion of flying accidents occur at night, and of

motoring accidents at twilight. Delayed dark adaptation is probably of importance also with reference to dazzling by strong head-lamps (Jeghers, 1937). The problem is therefore not of merely academic interest.

Glare has long been regarded as an important factor in the production of night-blindness. The classical instances are the Brazilian labourers who could see when setting out to work before sunrise but not when returning in the evening in 'better light' (de Gouvea, 1883); the soldiers who became night-blind after a parade in bright sunshine or the painter after painting a white façade (Lohmann, 1913); and the sailors in tropical regions (Forbes, 1811) or the fishermen in Newfoundland or Labrador who go night-blind in the summer unless they drink cod-liver oil (Aykroyd, 1930). These cases afford a clinical parallel to the experimental production of hemeralopia in the rats, to which reference has been made. Since the effect of exposure to bright light in cases of vitamin A deficiency is evidently cumulative and may become severe, it does not appear advisable to use in testing capacity for adaptation any experimental procedure which involves frequent or prolonged bleaching of the visual purple.

Present Investigation

The results to be presented now are preliminary to a study of diet in relation to health which has been begun in Aberdeen and will be carried out at other centres in Scotland and England. Methods similar to those adopted here and other more elaborate methods are in use at many research centres in Denmark, Belgium, the United States, and elsewhere (Edmund and Clemmesen, 1936; Jeans *et al.*, 1937; Jeans and Zentmire, 1934, 1936) for the purpose of discovering the extent to which deficiency of vitamin A exists and the daily requirements of vitamin A to ensure perfect health. It is not suggested that the amount which may be shown to be necessary to ensure the maximum possible efficiency of visual adaptation will necessarily be optimal for all functions, but it can be stated that the requirement for perfect health cannot be less than the amount needed to ensure perfect dark vision.

Assuming that a method has been found which will accurately measure the power of adaptation, the following main questions arise: (1) to what extent do differences in the power of adaptation occur; (2) can adaptation be improved by giving vitamin A; (3) is defective adaptation associated with habitual low intake of vitamin A; (4) is it possible to state with any degree of certainty what regular intake is required to maintain maximal power of adaptation. Only the first two questions will be discussed in this paper. As the investigation proceeds, data will be presented relating to the other two.

Description of Apparatus

Since the test was intended for use chiefly with children and a large series of observations was contemplated, it was necessary to have a method that would be simple and yet accurate, and, as it was proposed to examine children at different centres, the apparatus had to be self-contained and of such a size that it could be easily transported.

The test consists essentially in measuring the power of distinction under different illuminations. White cards devised by Edmund (1936) were used. They have printed on them the letter E in different shades, varying from a letter printed in black to one on which faint grey can just be distinguished against the white background. In the series of nine cards the "contrast" of the letter against the unprinted background decreases in geometrical pro-

gression. The "contrast" is measured by the difference between the diffuse reflecting powers of the unprinted and printed parts of the test card, divided by the reflecting power of the unprinted part, and for the successive cards of the series has the following values:

$$\frac{1}{10^0}; \frac{1}{10^{0.25}}; \frac{1}{10^{0.50}}; \frac{1}{10^{0.75}}; \frac{1}{10^{1.00}}; \frac{1}{10^{1.25}}; \frac{1}{10^{1.50}}; \frac{1}{10^{1.75}}; \frac{1}{10^{2.00}}.$$

To designate the individual cards the logarithms of the reciprocals of these fractions are used, so that the black letter on the white background corresponds to 0.00 and the faintest letter on the white background is designated 2.00: on this card the grey is so faint that its reflecting power is 99 per cent. of that of the white background. The letter is 63 mm. high; the breadth of the limbs 12 mm. This is slightly larger than the 6/36 letter on a Snellen chart. As the card is placed at a distance of about 40 cm. from the eye, the visual angle is large, so that even in very low illuminations where there is a physiological central scotoma, the letter can still be distinguished. To vary the apparent brightness, Tscherning's photometric glasses are used. These glasses are of a neutral grey tint and are so constructed that they absorb light after a logarithmic scale, No. 1 glasses transmitting 1/10 of the incident light, No. 2 glasses 1/10², No. 8 glasses 1/10⁸. The two 60-watt lamps used give an illumination on the card of 1,670 metre-candles. When the cards are viewed through the series of Tscherning glasses the apparent illumination is reduced, as in the following table:

Tscherning Glass No.	1	2	3	4	5	6	7	8
Apparent illumination in metre-candles	167	16.7	1.67	0.167	0.0167	0.00167	0.000167	0.0000167

Since this investigation had to begin on a certain date to fit in with other clinical studies, there was not sufficient time to measure the illumination used before starting the clinical work. After the apparatus had been in use for some time it was suspected that the illumination was higher than that used by Edmund (1936), since several subjects were found who could see card 0.50 through the No. 8 glass. Later, physical measurement showed that the illumination was 1,670 metre-candles (8.22 Tscherning) instead of 1,000 metre-candles (8.00 Tscherning) as used by Edmund. Our curves may therefore be expected to be displaced to the right by 0.22 Tscherning relative to those given by Edmund.

ILLUMINATION OF TEST CARDS

The illumination of the test cards was determined as 1,670 metre-candles by comparison with a surface illuminated by a standard 10 candle-power Vernon Harcourt pentane lamp, using a photo-electric cell as a transfer instrument. A copper/copper-oxide photo-electric cell was fitted with a neutral grey glass filter of transmission coefficient 2.07 per cent. (1/48.2). Exposure of the combination of cell and filter in the plane occupied by the test type gave a deflection of 26.7 cm. on a moderately sensitive galvanometer connected to the cell. The cell, without the filter, was then exposed at 54 cm. distance from the pentane lamp (with appropriate diaphragms to eliminate scattered light), and a galvanometer deflection of 26.4 cm. was observed. The intensity of illumination of the test type was therefore:

$$\frac{10}{0.54^2} \times \frac{26.7}{26.4} \times 48.2 = 1,670 \text{ metre-candles or lux.}$$

Conversion to the Tscherning scale of brightness may be made to an adequate approximation by assuming that 1,000 lux corresponds to Tscherning 8. The illumination of the test cards would therefore be $(\log_{10} 1670 + 5) = 8.22$

Tscherning; or if a reflecting power of 75 per cent. is assumed for the white card the brightness will be 8.09 Tscherning.

EFFECT OF FLUCTUATION OF SUPPLY VOLTAGE DURING TESTS

Fears that fluctuation of the voltage of the electric supply might vitiate the results by causing serious variation in the illumination of the test cards were found to be without foundation. Observations extending over several days with a self-recording galvanometer connected to the photo-electric cell showed that the maximum variation of illumination amounted to ± 15 per cent. (voltage variation ± 5 per cent.): during the forenoon hours, when most of the tests were done, the variation was only ± 7 per cent., or ± 0.03 Tscherning. Apparatus for control of input voltage was therefore unnecessary for the purpose of the tests. The details of construction of the test-cabinet are shown diagrammatically (Figs. 1, 2, 3, and 4).

FIG. 1.—Front elevation.

FIG. 2.—Front elevation (face removed).

FIG. 3.—Side elevation.

FIG. 4.—Back elevation.

COST OF APPARATUS

	£	s.	d.
Test type	3	1	3
Import duty		13	0
Tscherning photometric glasses (small) ...	6	16	6
Import duty		3	8
Box: material and cost of making ...	3	10	8
Total	£17	9	8

Test type from Nyrop and Maag A/S., Copenhagen; Tscherning photometric glasses from Guilbert, Routit et Cie, 114, Rue du Temple, Paris (III); box: home made.

FIGS. 1, 2, 3, and 4:

The cabinet is 19 inches long, 13 inches deep, and 19 inches high. The lettering is as follows:

- A: a light-tight box;
- B: carrier for the Tscherning glasses (C);
- D: wooden holder for the lens carrier;
- E: brass eyepiece;
- F: wooden tube;

G: Card carrier to hold two cards, sliding in the runners (H); while one card (K) is opposite the opening (J) another card (K') can be fitted into the carrier and when the first card (K) is recognized by the patient the carrier is pushed along, causing the second card (K') to come opposite the opening (J);

I: two racks to hold the series of cards;

L: two 60-watt translucent electric globes.

Technique

The test is performed in a dark room. Card 0.00 is placed in the carrier G, the card being then opposite the opening J. Card 0.25 is fixed in the other space in the carrier. The slide is pushed along until glass 8 is opposite the eyepiece. The nature of the test is carefully explained to the subject. The cards with the letter E are shown, and the subject is made to understand clearly that no

other letter will be shown, and he is required only to say in what direction the E is pointing. Only children capable of doing this have been tested so far. Before beginning the test the subject is kept in the dark room for at least fifteen minutes. If the position of the E is correctly given for the 0.00 card the slide is pushed across so that the 0.25 card is now opposite the opening. When the subject fails to distinguish the direction, the Tscherning glasses holder is pushed along, and glass 7 comes opposite the eyepiece. The subject is then looking at the card that he just failed to see through the darker glass. This procedure is continued until a card value has been found for each of the Tscherning glasses. The values so found can then be shown in graph form. Illustrative examples are given below.

Time Allowed for the Eye to Become Dark Adapted.—The time taken for ten normal individuals to see card 0.00 through glass 8 was as follows:

4 individuals saw card 0.00 through glass 8 in 5 minutes.

4	"	"	"	7	"
1	"	"	"	10	"
1	"	"	"	12	"

Twenty normal individuals were kept in darkness for times varying from fifteen to sixty minutes. No appreciable difference could be found in the adaptation curves of these individuals. It can therefore be stated that if an individual be dark-adapted for fifteen minutes the adaptation will be approximately at its upper limit for that individual.

Time Taken to Complete the Test.—The time taken by 100 individuals to complete the test varied from seven to fifteen minutes. By prolonging the test in repeat examinations no higher values could be obtained. About ten minutes for the complete test is, in most cases, adequate.

Factors which may Influence the Test

Pathological eye conditions, such as retinitis pigmentosa and chronic glaucoma, which are known to cause night-blindness were excluded from this investigation. All patients received a complete ophthalmological examination, and only those that had normal visual acuity were examined for dark adaptation. Several of the children wore glasses. This did not appear to have any influence upon the adaptation curve.

Practice was another factor which might have influenced the test. The essentials of the test were clearly demonstrated before actual testing was begun. The method is so simple and easily understood that children of 6 years of age with normal intelligence had no difficulty in understanding what was required. A slight improvement only was found in the adaptation curve of university students upon repeating the examination a week later under similar conditions (Table I; Fig. 5). When a similar experiment

FIG. 5.—Effect of practice on ten university students. The shaded zone represents the upper and lower limits of normal adaptation.

was performed upon seven East End school children a negligible improvement was noted through glass 7 only. This improvement could quite easily be accounted for by the fact that these children were examined on the two occasions on the same forenoon and kept in the dark from the beginning of the first until the end of the second test. The first test was started on the first subject ten minutes after entering the dark room, and an even greater improvement in the adaptation curve might have been expected from increase in dark adaptation. It can therefore be stated that in our experience practice has little or no influence on the accuracy of the test.

Normal Power of Distinction

The individuals who have been examined number 130. The majority of them have been tested twice; about fifty have been examined three or four times. These preliminary studies include ten university students, twenty mill girls, twenty industrial school boys, and twenty-three children of employed and unemployed working-class

FIG. 6.—Effect of 16,000 units of vitamin A on two university students. The shaded zone represents the upper and lower limits of normal adaptation.

parents, for whom the average results are shown in the tables and graphs. After completion of the first test a single dose of 16,000 units of vitamin A, as halibut-liver oil,* was given to two of the university students and to all of the other subjects, and a second test made one hour afterwards. It will be seen that little improvement fol-

FIG. 7.—Effect of 16,000 units of vitamin A on twenty mill workers. The shaded zone represents the upper and lower limits of normal adaptation.

lowed the taking of vitamin A in the case of the university students (Fig. 6), but a definite improvement occurred in all other cases (Figs. 7 and 8). A similar dose of vitamin A was given on each working day and each school day for a fortnight to those of the mill workers who gave unusually poor first curves and to the elementary school children. The mill girls showed a dramatic improvement at the end of the fortnight, but the elementary school children little improvement beyond that produced by the single dose, except at the two ends of the scale, where

* The capsules of halibut-liver oil used were kindly supplied, without charge, by Messrs. Crookes, to whom we express our thanks. Stated value, 8,000 international units per capsule.

FIG. 8.—Effect of vitamin A on twenty industrial schoolboys. The shaded zone represents the upper and lower limits of normal adaptation.

the improvement was definite (Fig. 9). On testing these children again, a fortnight after stopping the vitamin A, a slight decrease in adaptation was found, but not to the level of the first test.

FIG. 9.—Effect of vitamin A on twenty-three working-class children. The shaded zone represents the upper and lower limits of normal adaptation.

It may therefore be tentatively suggested that the performance of the university students—and of other adults of similar class, tested but not here recorded, who gave similar results—is such as to be unaffected by increase in vitamin A intake, and is therefore optimal. A large proportion of the other subjects did not attain this standard, and these, without exception, improved after administration of vitamin A. On the basis of these results it appears that any subject giving an initial curve below the following may be expected to respond to vitamin A:

Tscherning Glass No. . .	8	7	6	5	4	3	2
Test card	0.25	0.50	0.75	1.00	1.25	1.50	1.75

It also appears that the most perfect curve that can be expected will be:

Tscherning Glass No. . .	8	7	6	5	4	3	2
Test card	0.50	0.75	1.00	1.25	1.50	1.75	2.00

These limits are represented in the graphs by the shaded area.

A point that may be of practical importance is that administration of vitamin A very definitely affects not only the vision at minimum illumination (glasses 8 and 7) but also the power of distinction at an illumination equivalent approximately to twilight (glass 4), and even at the highest illumination and in daylight.

TABLE I.—Ten university students, aged from 18 to 21 years

Test	Tscherning Glass No. . .	8	7	6	5	4	3	2
A	Test card	0.22	0.57	0.85	1.05	1.37	1.57	1.75
B	" " " " " " " " " " " "	0.27	0.60	0.80	1.07	1.40	1.70	1.75

A, first test; B, repeat test one week later.

TABLE II.—Two university students

Test	Tscherning Glass No. . .	8	7	6	5	4	3
A	Test card	0.37	0.75	0.75	1.12	1.37	1.50
B	" " " " " " " " " " " "	0.25	0.50	0.75	1.12	1.37	1.75

A, first test; B, one hour after 16,000 units of vitamin A.

TABLE III.—Twenty girls employed in a cloth mill, aged from 15 to 24 years

Test	Tscherning Glass No. . .	8	7	6	5	4	3	2
A	Test card	0.01	0.35	0.72	0.91	1.22	1.47	1.61
B	" " " " " " " " " " " "	0.12	0.50	0.92	1.12	1.37	1.60	1.83

A, first test; B, one hour after 16,000 units of vitamin A.

TABLE IV.—Three selected cases from the above series who showed an abnormally low adaptation curve

Test	Tscherning Glass No. . .	8	7	6	5	4	3	2
A	Test card	—	0.18	0.50	0.75	1.16	1.41	1.58
B	" " " " " " " " " " " "	0.00	0.50	0.83	1.16	1.33	1.58	1.83

A, first test; B, after 16,000 units vitamin A on working days for two weeks.

TABLE V.—Twenty industrial school boys aged from 12 to 16 years; average age 14

Test	Tscherning Glass No. . .	8	7	6	5	4	3	2
A	Test card	0.14	0.47	0.76	1.02	1.31	1.56	1.68
B	" " " " " " " " " " " "	0.25	0.65	0.90	1.13	1.36	1.57	1.85
C	" " " " " " " " " " " "	0.20	0.56	0.74	1.00	1.26	1.52	1.68

A, first test; B, one hour after 16,000 units vitamin A; C, repeat test one week later.

TABLE VI.—Twenty-three working-class children, aged 10 to 13 years

Test	Tscherning Glass No. . .	8	7	6	5	4	3	2
A	Test card	0.01	0.29	0.60	0.80	1.14	1.45	1.50
B	" " " " " " " " " " " "	0.12	0.55	0.80	1.00	1.30	1.55	1.55
C	" " " " " " " " " " " "	0.20	0.53	0.80	1.11	1.30	1.52	1.66
D	" " " " " " " " " " " "	0.05	0.50	0.70	1.10	1.40	1.50	1.66

A, first test; B, one hour after 16,000 units vitamin A; C, vitamin A for two weeks; D, two weeks later.

Summary

The estimation of power of dark adaptation by means of Edmund's hemeralopia test type and Tscherning photometric glass is described and preliminary results presented.

A limit is shown below which all subjects react with improved adaptation to administration of vitamin A. Those

whose first performance is above this limit give no response to vitamin A.

The test is sufficiently simple to be applied to intelligent children of 6 years, so short that it is suitable for serial examinations, and the results are unaffected by practice.

We have pleasure in acknowledging the co-operation of Dr. I. Leitch and Mr. D. Lubbock in organizing and carrying through this investigation.

REFERENCES

- Adams, D. (1929). *Med. Res. Coun. Spec. Rep. Series No. 127*.
 Aykroyd, W. R. (1930). *J. Hyg.*, **30**, 357.
 Berry, G. A. (1886). *Edinb. med. J.*, **31**, 1025.
 de Gouvea (1883). *v. Graefes Arch.*, **29**, Abth. 1, 167.
 Edmund, C., and Clemmesen, Sv. (1936). *Deficiency of Vitamin A and Visual Dysadaptation*. Levin and Munksgaard, Copenhagen;
 Humphrey Milford, Oxford University Press.
 Forbes, J. (1811). *Edinb. Med. and Surg. J.*, **7**, 417.
 Fridericia L. S., and Holm, E. (1925). *Amer. J. Physiol.*, **73**, 63.
 Holm, E. (1925). *Ibid.*, **73**, 79.
 Jeans, P. C., Blanchard, E., and Zentmire, Z. (1937). *J. Amer. med. Assoc.*, **108**, 451.
 — and Zentmire, Z. (1934). *Ibid.*, **102**, 892.
 — (1936). *Ibid.*, **106**, 996.
 Jeghers, H. (1937). *New Engl. J. Med.*, **216**, 51.
 Lohmann, W. (1913). *Disturbances of the Visual Functions*. John Bale, Sons and Danielsson, London.
 Lythgoe, R. J. (1926). *Med. Res. Coun. Spec. Rep. Series, No. 104*. Privy Council (1863). Fifth Rep. of M.O. for 1862.
 Snell, S. (1876). *Lancet*, **1**, 8.
 Spicer, H. (1892). *Ibid.*, **2**, 1387.
 Tansley, K. (1931). *J. Physiol.*, **71**, 442.

MODERN METHODS OF TREATMENT OF CLUB-FOOT*

BY

DENIS BROWNE, F.R.C.S.

Surgeon, Hospital for Sick Children, Great Ormond Street

It is very flattering but slightly uncomfortable for one who is not an orthopaedic surgeon to be invited to open a discussion at an orthopaedic meeting. However, in the present interesting but undeveloped state of surgery it is probably useful for someone to work at right angles to the accepted lines of specialization, limiting his cases by their age rather than by the system of the body that is affected. So, taking advantage of my position as an amateur orthopaedist, I will start with the platitude that before beginning to treat a condition it is of advantage to decide what that condition actually is. In the case of talipes I believe that this can be done.

The Cause of Talipes

The teaching at present is that the cause of talipes is unknown. I believe, on the contrary, that it is possible to establish beyond doubt the existence of a definite category of congenital deformities due to mechanical causes, and that the classical "talipes equino-varus" is the middle range of a certain series of these deformities. It has been an interesting task working out the limits and possibilities of this category, and I have given elsewhere a summary of the evidence I have collected on the subject (1936). The result has been to convince me that these congenital deformities of the feet are only understood in all their degrees of severity and all their complications and variations when looked at in this light; and that this understanding is a not entirely negligible help to their treatment.

* Read in opening a discussion in the Section of Orthopaedics, including Treatment of Fractures, at the Annual Meeting of the British Medical Association, Belfast, 1937.

It is interesting to examine the causes that prevent the general recognition of what I believe to be an important and definite pathological category. First among the difficulties comes the complication of the argument. Even to state it properly would be a long day's work, and no one could possibly imagine a busy surgeon devoting a day to listening to it. No journal would publish such a statement except in a form compressed to the verge of unintelligibility; a book on the subject might have a sale of a dozen copies; and meetings of this sort are in their hurry a poor substitute for the leisurely courts of argument of the mediaeval schoolmen.

Then the mental process employed is one that is almost entirely neglected in medicine. We have become used to depending on the fruitful and valuable experimental method, in which we produce artificially certain happenings, observe them, and draw conclusions. But there is another method used in science. No one can play experiments on the planets, but yet we know a good deal about them. We have learnt it by reasoning out what would happen were a certain hypothesis true, and comparing these results of abstract thought with what actually does happen.

It is on this second plan that I have tried to investigate the group of congenital deformities to which I consider talipes to belong; and it is because of its unfamiliarity in medicine that very few of my colleagues seem to see the line of argument or admit its strength. The reason for using it is that it is notoriously difficult to interfere in the processes of gestation without wrecking it. I can think of certain experiments that would confirm my results, but to me they appear simply unnecessary cruelty. And, after all, the Chinese have done some fairly relevant experiments on the female human foot. Shortly, the argument is that if one works out in the abstract what would be the consequences of certain things going wrong in the delicate correlation between the growing foetus and its expanding surroundings, one can deduce a series of deformities exactly duplicated over a period of years in the outpatient department of any children's hospital.

Certain stock objections to this theory are made, usually with a kind of hint that the objector could easily think of more, and stronger ones, if it were worth his while. They all seem to me to show a failure to grasp what the hypothesis attacked actually is. For instance, Middleton (1934) says that the negative is proved once for all by the occurrence of talipes in foetuses 3 months old. I believe that compression can begin its work when the foetus is two millimetres long. Burns and Ellis (1937), remarking that there are many cogent arguments against it, give as a sample of them that in the early days of pregnancy the foetus can move freely within the uterus. I have been unable to find any work illuminating this point, but granted the freedom of movement to be as great as it is usually thought to be, this freedom seems a curious argument against the possibility of displacement. And, anyhow, it is no part of the hypothesis that the displaced feet have ever been in normal position; the probability is all the other way. If any one really wants to attack my hypothesis, here are some of the main lines of argument which have to be explained away.

1. The position of the normal foetus before birth.—I believe the drawings of the foetus in textbooks of obstetrics to be inaccurate in certain very important points.

2. The position and range of movement of the feet in the newborn infant.

3. The occurrence of "pressure dimples"; a most interesting line of argument.—Their variations according to degrees of pressure, and normal or abnormal positions of the limbs, seem