proximal part of the flexure of the small colon which may be so calcified as to appear like the stem of a clay pipe (Pl. 2, 2) with the lumen of the gut almost completely obstructed. Histologically the lesions resemble those characteristic of hypervitaminosis D.

Summarizing, I would say that unless an adequate diet is provided at all times to breeders and growers, the door may be opened to epidemic disease with disastrous results, or the results of experiments will be difficult to interpret if guinea-pigs matched in weight vary greatly in age or guinea-pigs of the same age vary greatly in physiological development. I would also suggest that the nutritional requirements of the guinea-pig require further study particularly in regard to the part played by hay.

REFERENCES

Bruce, H. M. (1950). *J. Hyg., Camb.*, **48**, 338.
Bruce, H. M. & Parkes, A. S. (1947). *J. Hyg., Camb.*, **45**, 70.
Cassidy, J. (1957). *Proc. Nutr. Soc.* **16**, 63.
Lane-Petter, W. (1957). *Proc. Nutr. Soc.* **16**, 59.

EXPLANATION OF PLATES

Pl. 1. Effect of a hay-free diet on guinea-pigs. (1) and (2) Female guinea-pig 2 days after onset of signs. (3) Lateral view of head showing overgrown incisors. (4) Anterior view of skull showing overgrowth of all teeth.

Pl. 2. Guinea-pigs with 'soft tissue calcification'. (1) An 18-month-old male guinea-pig which has shown signs of the disease for 2 weeks (left) compared with a normal male of the same age. (2) Two male guinea-pigs with advanced signs of the disease, particularly in the flexure of the small colon.

Monkey welfare

By E. M. Hume, *Lister Institute of Preventive Medicine, London, S.W.*1

Rickets and its prevention

Outside the tropics monkeys have to be kept largely indoors where the direct sun does not reach them except through glass, and it is indispensable for their welfare as laboratory animals, as zoo exhibits or as pets that they should be properly protected against rickets if they are young animals and against osteomalacia if they are adult. I am not sure how far the battle to prove that is completely won even now. Forty years ago monkeys were said to have cage paralysis when they lost the use of their legs in captivity. That term seems to have disappeared but there is still considerable neglect to provide an adequate supply of vitamin D in some form.

I became interested in monkeys in the First World War when I had a motley collection that I got together at the Lister Institute for our nutritional studies, more particularly on scurvy. The aetiology of rickets was then still uncertain. Sir Edward

Mellanby was engaged upon his classic experiments with dogs, and after the end of the war I went with Dame Harriette Chick to Vienna to study rickets and hunger osteomalacia. When I was at home again for a short time I saw that two of my monkeys had developed rickets during my absence. They had been losing weight slowly on an experimental diet, and then had regained weight on a normal diet and begun to grow at a phenomenal rate.

Pl. 1, 1 shows the X-ray picture of the wrist of one of those two monkeys, an African *Cercopithecus* sp., called Tom. The enormously wide epiphyseal cartilages and frayed ends of the diaphyses are like those in human rickets. The other monkey was a young rhesus called Jon. The X-ray picture of his wrist is highly abnormal too but does not so closely resemble that usually seen in human rickets.

I was by this time highly sensitized to rickets, and when I walked round the Zoological Society's Gardens in Regent's Park, it appeared to me that many of the monkeys there had rickets too. They could not walk and pulled themselves about in a sitting position with the so-called cage paralysis. Also, they never bred in captivity.

I could not investigate the matter further for several years, but when we had finally returned from Vienna, I began, with the co-operation of Miss H. Henderson Smith, to look for monkeys with what we believed to be rickets, in order to see whether, like human infants, they could be cured by exposure to the ultraviolet rays of a mercury-vapour quartz lamp. The Zoological Gardens would not co-operate and refused to let me have even palpably deformed monkeys for treatment, but by the courtesy of the then Lord Rothschild I obtained a rare and beautiful Congo mangabey, *Cercocebus* sp., deposited by him in the Zoo but still his property. She could not walk at all, she could only sit, but she was not obviously deformed.

Pl. 1, 2 shows the X-ray picture of her wrist, taken on 3 March 1926 when she first came to the Lister Institute. She was a relatively older monkey than the *Cercopithecus*, Tom. The epiphyseal cartilages are not nearly so wide but the metaphyses are broadened and much rarefied, and the edges are frayed. With regular ultraviolet-light treatment she gradually regained the use of her legs, and could walk, run and jump. An X-ray picture taken on 8 June, after 3 months' treatment showed considerable consolidation of the bone but it was still highly abnormal. The picture was a bad one as she moved. In November, after 8 months in all, she unfortunately contracted pneumonia and died. An X-ray picture was taken *post mortem*, and shows great healing (Pl. 1, 3). The bones have grown in length and, beyond the severely rachitic area where rarefaction can still be seen, there is a better modelled, better calcified portion of the shaft with a clearly defined epiphyseal margin.

She was a lovely creature with a beautiful little cap of stiff black hair, and a flesh-coloured face with black blotches which gave her her name of Freckles. I imagine Freckles is the first monkey in which healing of rickets was demonstrated radiographically.

Details have been given of these three monkeys, Tom, Jon and Freckles, partly because they were the first I dealt with, and partly because they belonged to representative genera, one Asiatic, *Macaca*, and two African, *Cercopithecus* and *Cercocebus*,

of Old World monkeys, which are, on the whole, less liable to rickets than New World monkeys, and whose liability to rickets is possibly still doubted. The New World monkeys are more delicate and require a higher temperature than the Old World monkeys and consequently are kept more strictly indoors with little if any access to light except through glass. They can develop rickets within the 1st year of coming to England.

Quantities of New World monkeys gradually came into our hands for treatment. The various pet shops had learnt that we were interested to see whether we could cure rickets in monkeys. So, when their customers came back to them saying 'the monkey we bought from you has lost the use of its legs,what can you do about it?', they were sent to us at the Lister Institute. In this way we saw a great many marmosets, capuchin monkeys, woolly monkeys and three beautiful Geoffroy's tamarins belonging to the late Lord Moyne. At the other end of the social scale their pets were brought by a servant maid and by a publican and his wife. I do not think we ever failed to cure. Deformities of course remained, but the bones were hard, and the excruciating pain like that of human osteomalacia disappeared completely.

Thus, there remained no doubt at all that monkeys in captivity, whether from the Old World or the New, were highly susceptible to rickets when kept indoors behind glass, and that rickets was the most important source of their ill health.

Breeding with ultraviolet light from an artificial source

In co-operation with Dr N. S. Lucas we next turned our attention to breeding monkeys. If rickets was prevented by regular treatment with ultraviolet light we hoped to find that the great obstacle to breeding was removed. We proved that it was so. Our work in breeding the common marmoset, *Hapale jacchus*, L., with the help of ultraviolet light has been published (Lucas, Hume & Smith, 1927, 1937) and so need be dealt with only briefly.

Our first attempt was not more than moderately successful, probably because our first pair of marmosets was rather elderly. They had, however, one or two living offspring, of which one, Evil, the first English marmoset, lived to be adult. He had the characteristic white ear tufts and the ringed tail, but the rest of his coat did not have the normal colouring.

A younger pair of marmosets achieved complete success and in the course of 7 years had twenty-four offspring, usually as twins, sometimes as singletons, and twice as triplets. We mated the daughters with the sons and sometimes also with males reared by Miss Doris Hill, to whom we had taught our methods, but we never succeeded in rearing a second generation. The cause was not sterility but a ghastly series of obstetrical catastrophes. Instead of the normal twins there would be three or even four large embryos which could not be born, and mother and offspring perished. Miss Hill had somewhat the same experience but she did succeed in raising one or two young of the second generation. The explanation was a mystery until it was suggested to me by Professor F. H. A. Marshall that the exposure to ultraviolet light probably overstimulated the pituitary gland (Marshall, 1936, 1937). It seems

likely that that is the explanation, for even the old mother marmoset in her last two pregnancies had triplets, and a very young forest-born marmoset that we had reared with ultraviolet light came to the same tragic end. Miss Hill had an ultraviolet lamp very much less potent than ours. It was only a small carbon arc, and the pituitary gland in her marmoset would not have been so grossly overstimulated, so that a successful pregnancy was possible.

Other methods of preventing osteomalacia and rickets in monkeys

We were never able to make any study of the amount of ultraviolet light that would have been enough and not too much, and we did not accumulate very much information about other methods of supplying vitamin D. We did, however, have some experience with a pair of South American squirrel monkeys, *Saimiri sciurea*, which the Zoo authorities considered to be one of the most delicate and difficult kinds to keep.

Some preliminary attempts showed us that they needed a longer exposure to ultraviolet light to prevent rickets than the marmosets. The pair we obtained were quite young monkeys, not much more, we thought, than 6 months old. They lived for 10 years at the Lister Institute in Chelsea and grew up to be beautifully healthy and active. They weighed about 300 and 400 g when they came to us and took between 4 and 5 years to reach their adult weight of just under 1000 g (Fig. 1). In September 1939 they were evacuated with us to Cambridge. Ultraviolet light could no longer be provided for them, nor could they have much of their accustomed

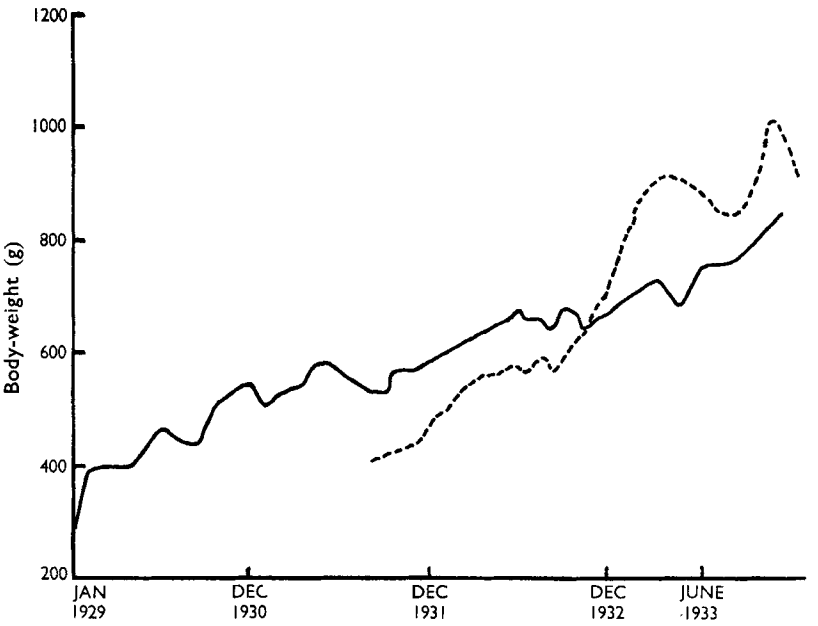

Fig. 1. Weight curves of a pair of South American squirrel monkeys (*Saimiri sciurea*) from the presumed age of about 6 months to the attainment of their adult weight. Large fluctuations in weight represent only changes in the degree of obesity. There were no illnesses. ———, female; - - - - - -, male.

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food. The male quickly began to go to pieces and died in a couple of months. The female, Olive, began to stiffen and by January 1940 could no longer jump. I was fortunately able to get some Vitaglass, which transmits ultraviolet light, and have it put into a window of the conservatory, which was our animal house, so that the sun shone directly on to Olive. She soon regained her activity and never lost it in the ensuing 6 years which she spent in the same conditions. One can, therefore, say that even winter sun coming directly through Vitaglass, kept scrupulously clean, was sufficient to avert the impending ostemalacia and prevent its ever recurring.

When we returned to the Lister Institute in 1946 we had to have recourse to giving vitamin D by mouth, and Olive then received dried milk containing vitamin D_2 and a high concentrate of vitamin D as calciferol put into her milk. She survived for another 4 years by which time she was 21 years old. She then gradually failed for no obvious reason except extreme old age. Her post-mortem examination was made at the Zoo in the Prosectorium. Our teaching had by then been accepted and our methods, at least partially, applied there (Anonymous, 1951). The hatchet was buried in Olive's grave. The report on the autopsy was that changes of such extreme senility were very rare in so small an animal, less than 1000 g in her prime (Hume & Smith, 1951; Rewell, 1954).

In summing up, one can say that all three ways of supplying vitamin D, from an artificial-light source, from the sun through Vitaglass, and as calciferol given by mouth, were successful in preventing rickets and osteomalacia and promoting normal growth and health, except for the unfortunate effects on the second generation of marmosets of what was probably an excessive supply of ultraviolet light. The two squirrel monkeys never produced offspring, for which we found no explanation, since they appeared to be sexually normal and mated frequently.

Our observations have an important bearing on the care of monkeys as laboratory animals. The results show that it is possible to maintain monkeys in the laboratory for periods so long that studies of psychology and breeding habits can be made. For studies of shorter duration such, for instance, as those on immunity, they make it clear that prophylactic treatment with vitamin D ought to be given as a routine with no exception. It has often been said to me that such precautions are unnecessary for monkeys on short experiments, since it is obvious that they do not get rickets. To which one must reply that, though they do not show signs of rickets, it is most probable that they are in negative calcium balance, and one does not understand how a conscientious investigator can be content to make experiments on animals in a state of metabolic abnormality, varying in its degree of severity.

Diet

It should not be made to appear that with the prevention of rickets all the needs of monkeys have been met. Their diet is of the very greatest importance, but it is hard to generalize about it. Of most monkeys one would say that they abhor monotony. One day they will fall upon a new food and devour it passionately. If it is given every day, after a few days they will not look at it. The common laboratory monkey,

the rhesus, is such a one. Being crop robbers, they enjoy dry pulses and cereals and if, for instance, they have not had dried peas for some time and then receive them, every monkey in the room will sit with its face swollen out to twice the normal size, having filled its cheek pouches with peas to be chewed at leisure. A few days later peas are scorned but dry rice will be accepted or dry wheat.

The diet should of course aim at being complete and, as it is mainly vegetarian, it should be varied and offer a good assortment of proteins. Milk greatly improves the condition of most monkeys but it is difficult to get it taken before it is spilt or contaminated with foreign matter. Rhesus monkeys can have boiled rice, wheat germ, boiled potatoes, raw carrots, raw cabbage and lettuce, apples and many other fruits if not too expensive, bread, nuts and dried cereals and pulses. I have heard that laboratory monkeys are being fed on cubes. I cannot imagine how they can thrive on cubes. The diet for rhesus is probably suitable for many other Old World monkeys.

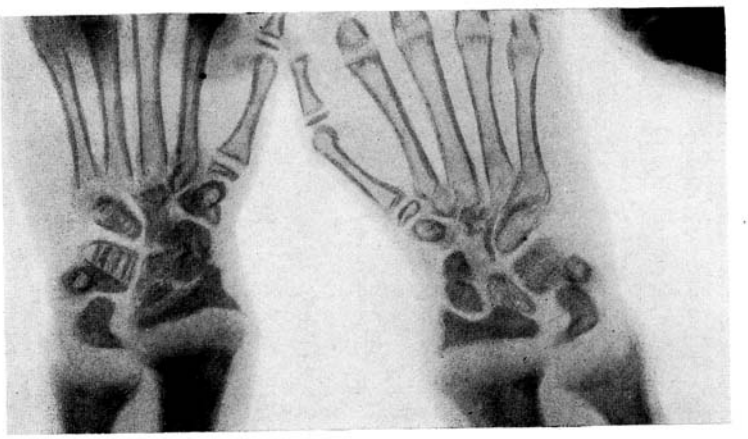
New World Monkeys will often take insects, and mealworms are passionately liked. Of our two squirrel monkeys, the male was very restricted in his tastes; he would take boiled rice, grapes, banana and other bits of fruit, nuts, small birds' eggs and newborn rats. He took a little milk by dipping his hand into it and licking it or by drinking from a half walnut shell or egg shell after Olive had filled it with milk. After he died and with the scarcities of wartime, she ate almost anything, from boiled onion or leek to fat bacon and chicken bones. She was intelligent enough to try everything. The marmosets on the other hand were very restricted and conservative; milk, banana, boiled rice, grapes and mealworms were their staple diet and they did not seem to tire of it. When the babies began to eat they never took anything except from a parent's hand, so, as with human parents, the limited tradition was easily maintained. For all monkeys we saw to it that they were never without food. Like birds they seem always to be picking about and eating something, particularly the little New World monkeys.

Beverages

If milk is supplied and drunk, water may not be touched, but some drink should be always available. Many explanations are given of why monkeys in captivity bite their tails and lick the blood. A number of the monkeys I had in the First World War did so when they first came to me and had much abbreviated tails. With me they had regular drinks of milk or water, and tail biting always ceased and was not resumed. The observation is a purely empirical one, and I claim no more for it than that.

Temperature

I am not prepared to lay down any rules about the temperature at which monkeys should be kept. All of them seem able to respond to a temperature lower than that in their homeland by growing a thicker, sometimes an enormously much thicker, coat. I have seen rhesus at the zoo, kept out of doors all the winter, with a coat that



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looked like an old-fashioned coachman's cape. New World monkeys seem unhappy if the temperature goes below about 70°F., and like it much hotter.

Exercise

Of course, the more space monkeys can have the better, but healthy monkeys can take an astonishing amount of exercise in a very small space.

General considerations

We have often been told that our success with monkeys was due to detailed attention and fussing, but I do not think that is the whole truth. Monkeys hate to be alone and, if they have no monkey company, demand human company. After her mate died Olive became a pet, but our marmosets were not pets. They were a family group and provided their own society. They had clean cages, not at all large, food, drink, bed boxes and bedding and ultraviolet light; the rest they did themselves. I am sure other equally interesting and attractive family histories, with non-tame monkeys of other kinds, could be obtained by following the same methods.

REFERENCES

Anonymous (1951). *Zoo Life*, **6**, 1.
Hume, M. & Smith, H. H. (1951). *Zoo Life*, **6**, 3.
Lucas, N. S., Hume, E. M. & Smith, H. H. (1927). *Proc. zool. Soc. Lond.* p. 447.
Lucas, N. S., Hume, E. M. & Smith, H. H. (1937). *Proc. zool. Soc. Lond.* A, **107**, 205.
Marshall, F. H. A. (1936). *Phil. Trans.* B, **226**, 423.
Marshall, F. H. A. (1937). *Proc. roy. Soc.* B, **122**, 413.
Rewell, R. E. (1954). *J. Path. Bact.* **68**, 291.

EXPLANATION OF PLATE

X-ray photographs of the wrist of two monkeys.

1. African monkey, Tom, *Cercopithecus* sp. Florid rickets.
2. Congo mangabey, Freckles, *Cercocebus* sp. Severe rickets, 3.iii.1926.
3. Same as 2 but with rickets healed after treatment with ultraviolet light, 20.xi.1926, *post mortem*.

Some aspects of the feeding of dogs and other carnivora

By G. H. Bourne, *Department of Histology, London Hospital Medical College, London E.*1

There are about 20 million dogs in the United States and about 3½ million in this country. The American dogs consume about half a million tons a year of canned food and dry feed, and the importance of domestic animals in Britain's economy has