Severe undernutrition in growing and adult animals

10*. The skin and hair of pigs

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In the first paper of this series (McCance, 1960) it was stated that the undernourished pigs had highly abnormal skins and the abnormality was cured by rehabilitation. It has subsequently been discovered that the hyper- and para-keratosis observed were largely due to acarine parasites. This was not suspected at the time owing to the beneficial effects of rehabilitation. By dusting the undernourished animals with a Gammexane powder it has now been found possible to keep the skins free of parasites and avoid all the abnormalities which had been so conspicuous before. A study has now been made of the effects of undernutrition and rehabilitation, uncomplicated by parasitic infection, on the skin, hair and apocrine glands, and a parallel study has been made of the changes in normal development.

Previous work on the development of hair has largely been confined to mankind, sheep and rats. The follicles in man are all defined at birth and were at some time in foetal life equally spaced over the whole surface. Schultz (1931) considered that there was an increase in the number of hairs in specified parts of the body in primates, but most now agree that the final population per unit area, which is never so great as it was at birth, depends upon the extent to which the follicles are spread by the increase in the surface area of the part. There is no destruction of follicles after birth (Rothman, 1953; Szabó, 1958; Ryder, 1958). The same follicles may produce several types of hair, one after the other (Butcher, 1951; Garn, 1951). Hairs usually get thicker more or less rapidly after birth (Trotter & Duggins, 1948; Rothman, 1953), but they may get thinner again later in life if the parts are going bald.

The effects of a general restriction of food and of specific nutritional deficiencies on hair growth have also been investigated. Jackson (1932) showed that when newborn rats were held at their birth weight for 13 days their hair erupted towards the end of the 1st week instead of on the 2nd day and thereafter developed slowly but normally. Butcher (1939) made similar investigations on weanling rats and showed that undernutrition delayed the time of appearance of the secondary coat and its rate of growth. Undernutrition in mice also has been shown to delay the growth of hair (Lowenthal & Montagna, 1955), and in sheep the relation between nutrition and wool growth is a matter of considerable economic importance. The plane of nutrition before and just after birth can alter the rate at which the 'secondary' follicles develop and also their

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number (Schinckel, 1955*a*, *b*; Short, 1955), and later on it can affect the rate of growth, spacing, fibre diameter and weight of wool produced (Henderson, 1953; Joubert, 1954; Daly & Carter, 1955; Marston, 1955). Protein deficiency in children, producing the disease known as kwashiorkor, affects both the colour and texture of the hair (Trowell, Davies & Dean, 1954; Brock, 1961).

The effects of development and nutrition on the chemical structure of the hair are small compared with the physical and structural ones, but the hairs of mature animals have been found to contain slightly more cystine than those of young ones (Tadokoro & Ugami, 1930; Okuda & Katai, 1936).

EXPERIMENTAL

The pigs belonged to the laboratory colony except for one or two of the older animals needed for the age controls. The colony had originated as a cross between a Large White and an Essex, but subsequently the sows were always mated with pure-bred Large White boars and there were no dark hairs on any of the undernourished animals. The pigs used for studying the effect of development were normal female animals. The technique for rearing undernourished pigs has been described (McCance, 1960).

The skin and hair over an area situated not far from the backbone, and somewhat nearer the front than the back legs, were washed with water (occasionally with soap). The hair was combed and removed with a razor from an area which was carefully delineated and measured about 4×4 cm. It was sometimes necessary to sedate the animals with a little phenobarbitone sodium (Nembutal, Abbott Laboratories Ltd) intravenously in order to do it satisfactorily. The hair was collected in a weighed and stoppered jar and brought to the laboratory. The jar was then opened and the hair allowed to dry near a radiator for several hours or overnight. The contents of the jar were next transferred to black paper and the length of each hair was measured on a ruler with the aid of two pairs of fine forceps. The hair was finally dried in an oven at 50° until its weight became constant. Portions of skin were removed from the undernourished animals at death, and also from rehabilitated animals and from well-nourished controls of the appropriate weight and age. The sites chosen were the same as those used for the studies of hair growth. Two areas, each measuring 1 cm^2, were marked on the skin, which was then pinned on to a board and fixed. After fixation some of the squares were sectioned parallel to the skin surface, but most were cut into three rectangular blocks of equal size by two cuts vertical to the surface. Serial sections 10 μ thick were cut parallel to the long sides of the two outer blocks. Of every thirteen sections cut, the first three were mounted for examination. The apocrine glands were counted in each of these sections and the size of the groups of acini measured in a direction parallel to the surface of the skin. On the assumption that the glands were randomly distributed and of approximately equal radius, and that this radius was small relative to the length of the block (1 cm), the number of glands per cm^2 has been calculated from the formula $N = Lp \div (14b \div 11)$ where N is the number, $L = 1$ cm, p = the average number of the groups of acini found in the sections and b is their mean measured diameter.

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RESULTS

Table 1 shows the effect of development on the number of hairs/cm², their mean weight and length and the weight:length ratio. The number/cm² fell, and there was a steady increase in the mean weight, the mean length and in the weight:length ratio. This last figure was obtained by dividing the mean weight × 1000 by the mean length. The results substantiate the common observation that pig's hair becomes longer and coarser with development. Even within the laboratory colony, however, there were some differences between the animals at each age, but the effects of development were so much greater that these individual differences were neglected.

Table 1. *Effect of normal development on the characteristics of pig's hair*

			Characteristic of hair			
No. of animals	Age (months)	Weight (kg)	No./cm²	Weight/cm² (*a*) (mg)	Mean length (*b*) (mm)	Weight: length ratio*
4	1	6·4	119	0·05	11·5	4·4
4	4	39	28·7	0·24	18·7	12·8
4	6	84	18·1	0·92	44·8	20·5
5	9–12	156	13·7	1·76	56·7	31·0
3	15–22	190	9·6	2·65	64·9	40·8
3	36–60	250	6·1	5·38	66·9	80·4

* $\frac{a \times 1000}{b}$.

Table 2. *Effect of undernutrition and rehabilitation on the hair of pigs*

				Characteristic of hair			
	No. of animals	Age (months)	Weight (kg)	No./cm²	Weight/cm² (*a*) (mg)	Mean length (*b*) (mm)	Weight: length ratio*
Undernourished	7	9–12	5·2	128	0·14	21·4	6·5
Rehabilitated	2	36	190	14·5	2·49	64·7	38·5

* $\frac{a \times 1000}{b}$.

Table 2 shows the effect of undernutrition on the body-weight of animals aged 9–12 months, the number of hairs/cm², their mean weight and length and the weight: length ratio. Information about the hair in normal animals of the same size and age is given in Table 1. The undernutrition did not prevent some growth of hair, although it was sufficiently severe to hold the animals below the body-weight of other normal ones only 1 month old. There was no decrease in the number of hairs/cm², but their mean length increased considerably without much change in thickness. Table 2 also gives information about the effects of rehabilitation on the hair. The animals used for this study had been undernourished for 9 months. Rehabilitation allowed the hair to grow freely in length, and the number/cm² fell to about the level found in normal animals. The hair did not become so thick and coarse as in the oldest control pigs.

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Fig. 1 is a frequency distribution diagram of the hair lengths of the weight controls, the undernourished animals and their age controls, the rehabilitated animals and of the adult females for whom values are given in Table 1, line 6.

Table 3. *Effect of undernutrition and rehabilitation on the apocrine glands and hair density of pigs*

Type and age of animals	No. of animals	Weight (kg)	Weight$^{\frac{2}{3}}$ (kg) ('surface area')	Apocrine glands: No./cm^2	Apocrine glands: Apparent diameter (μ)	Hair No./cm^2
Undernourished, 9–12 months	5	5·3	3·05	108	498	116
Healthy 'weight' controls	2	6·2	3·37	132	430	119
Rehabilitated, 3 years	2	190	33·0	13	842	15
Healthy 'age' controls, 1–4 years	7*	240	38·6	18	949	12

* Three skins were obtained from Large White pigs which had not been reared in the laboratory colony.

Table 3 gives the effect of undernutrition and rehabilitation on the number of apocrine glands and hairs/cm^2 and on the mean measured diameter of the groups of acini. The normal effects of growth and development can be seen by comparing the findings in the 'weight' and 'age' controls. The number and dimensions of the apocrine glands and the density of the hair population in the undernourished animals were the same as they were in healthy animals of the same weight and approximately the same surface area. Normal healthy growth and rehabilitation increased the surface area by a little over ten times and reduced the number of hairs/cm^2 and the number of apocrine glands/cm^2 by about the same amount. Both effects may be attributed to the expansion in the surface area of the skin. The table shows that normal growth increased the diameter of the groups of acini, which also took place during rehabilitation.

DISCUSSION

In general terms the effects of development were those that might have been expected from the literature and a knowledge of pigs. These animals are very small at birth relative to their size as adults and the fall in density of the hair population may be attributed primarily to the expansion of their surface area. Atrophy, and the subsequent disappearance of follicles in certain parts of the body, has not been excluded by the findings in this investigation and may take place to some extent. With development the hairs became longer and thicker, and these changes were expressed quantitatively as means in Table 1.

Very little work has been done previously on the development of apocrine glands, certainly in the pig, but it would appear from this investigation that the full complement for the animal was in place by the 4th week of life, and may have been much earlier. With growth and increase in the surface area of the skin, the glands became separated laterally and the mean measured diameter of the groups of acini increased.

Undernutrition had several effects: (1) By holding the animals at such a small size

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for a year it prevented the normal expansion of the surface area and reduction of the hair and the gland population. It did not lead to follicular or glandular atrophy. (2) The hairs grew more slowly in length and much more so in thickness than they did in normal animals. This gave the effect of a long, thick silky coat. Some hairs grew much more than others and their length pattern as revealed by Fig. 1 was unlike the normal. The dimensions of the apocrine glands were not materially changed by undernutrition.

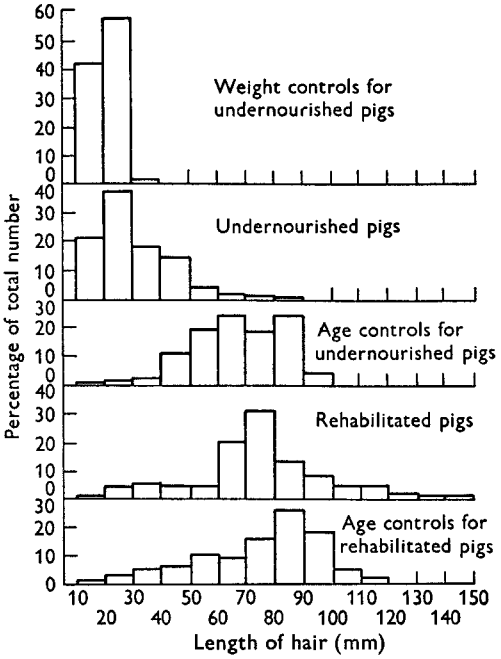

Fig. 1. Effect of undernutrition and rehabilitation on the length of pig's hair.

The growth of hair is closely linked with the function of the endocrine glands, particularly the gonads and adrenals. The former may account for some of the differences between the undernourished animals and their age controls. The effects of the adrenals are complicated (Butcher & Richards, 1939; Zeckwer, 1953; Johnson, 1957–8; Bush & Mahesh, 1959) and it is not possible to make any suggestions at present about their influence on hair growth in the undernourished animals. In earlier experiments, when the animals had parasites on their skins, the adrenals were enlarged (McCance, 1960) as they were also in the undernourished animals killed for this study.

Rehabilitation allowed the animals to grow freely. The two animals used for this investigation were sexually mature and had been mated successfully more than once. The number of hairs/cm^2 was very much less than it had been during undernutrition and although it was a little higher than in some of the animals of similar age and size it was of the same order, indicating that the change was due primarily to development and growth. This is borne out by the effects of rehabilitation on the number of apocrine glands/cm^2.

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SUMMARY

1. Hair was collected, weighed and measured from a defined area of back skin, and the number of glands/cm² was estimated histologically in normal, undernourished and rehabilitated pigs.

2. During development the density of the hair and the apocrine gland populations/cm² fell, and the hair became longer, thicker and heavier.

3. Undernutrition, by preventing growth, prevented the normal expansion in the animal's surface area and maintained a high hair and gland count/cm².

4. In spite of the undernutrition the hair grew slowly in length and to some extent in thickness. The result was a long silky coat.

5. Rehabilitation reversed the effects of undernutrition and allowed the hair to grow, but it may have remained rather thin for the age and size of the animal.

6. The apocrine gland counts/cm² fell, like those of the hairs, with the expansion of the surface area of the skin during rehabilitation.

The authors were greatly helped over the first counts of the apocrine glands by Messrs K. Maness and R. Tawes. Dr J. P. Dougherty provided the formula used for converting the mean number/cm to the approximate number/cm². Terry Cowan had sole charge of the pigs.

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