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Relation between heredity and environment

1. The problem of heredity and environment
2. Streaked, speckled and spotted sheep

GENESIS xxx, xxxi

I. THE PROBLEM OF HEREDITY AND ENVIRONMENT

The fact that parents transmit some of their characteristics to their offspring was known early in historical times and perhaps even many centuries before that. But the laws of heredity were formulated only in 1865 by Gregor Mendel. Possibly these laws were already known to Jacob in his handling of Laban's sheep (see below). Yet even if this assumption is accepted, it is clear that for thousands of years mankind erred in its quest for the apparently simple laws of heredity, due to two reasons: to the views of the disparate share of the male and female in transmitting their characteristics to the child, and to the different approaches to the question of the inheritance of acquired characteristics.

The roots of the view concerning the unequal share of the male and female in transmitting their characteristics to their offspring go back to very ancient

times. This view was developed mainly by the philosophers and naturalists of Greece and Rome, according to whom the woman is merely the receptacle for the growth and nourishment of the embryo, whereas the characteristics of the child, especially if it is male, derive from the father. This theory was also applied to the heredity of animals. The literature of the sages echoes this view, though in a somewhat sublimated form. There is, for example, the statement that a fixed division exists between the father and the mother in transmitting their characteristics to the child's various tissues and limbs:

The white substance (the spermatazoa) is supplied by the man, from whom come the (child's) brain, bones, and sinews; the red substance (the blood from which the embryo develops) is supplied by the woman, from whom come (its) skin, and blood; the spirit, the soul and the animation come from the Holy One Blessed Be He; and the three of them are partners in the child¹.

Despite this theory of 'topographical' distribution of the tissues transmitted by each of the parents, it was clear to the sages that the influence of the father's semen is not localized and limited to certain limbs, since 'the seed is mixed up' that is, it is involved in the formation of all the tissues, 'for if this were not so, the blind should produce blind offspring and the crippled a crippled offspring'². Despite the importance which the sages attached to the characteristics transmitted to the child by its father, in the case of animals they differed whether 'we must take the seed of the male into account,' while ascribing the main influence in the formation of the offspring to the mother³. It is nowadays clear that the character of the offspring is determined by the totality of both parents' characteristics.

The second problem that impeded a comprehension of the laws of heredity is the transmission of acquired characteristics. On this point there is a clash between common sense and the conclusions of science that the characteristics acquired by an organism during its lifetime are not transmitted by heredity to its offspring. It is a basic assumption in the Bible that during the six days of creation all the organisms, flora and fauna, were created. With regard to the flora, it is said that the third day saw the creation of 'grass, herb yielding seed after its kind, and tree bearing fruit, wherein is the seed thereof, after its kind'⁴, that is, every seed produces flora like its progenitors. The sages enunciated the principle: 'If a man puts different seeds in a bed, each grows in the manner of its own particular species'⁵. This has been proved by experience: 'Is it possible that you sowed wheat and barley came up?'⁶ These sources thus speak of the stability of the species in transmitting hereditary characteristics unchanged from generation to generation.

On the other hand, the literature of the sages contains views, most of which were current in the contemporary Graeco-Roman agricultural literature, that

the characteristics of the flora are liable to change under the influence of the environment, and that these changes are transmitted to the progeny. So, for example, the *Mishnah*⁷ declares that 'wheat and tares do not constitute diverse kinds one with the other,' the reason being that 'fruits degenerate,'⁸ that is, a man sows wheat which turns into tares, a prevalent view among the ancients. Galen even asserted that his father had proved it experimentally⁹, but against this Basilius¹⁰ rightly argued that tares and wheat are two different, discordant species. If tares are found growing among wheat, this is simply because seeds of the former, mixed with the grains of the latter, were sown together.

To this sphere of relation between heredity and environment belong the *halakhoth* according to which it is possible to obtain hybrids by grafting trees of different species. It is now known that in flora, as in fauna, hybrids can be produced by sexual impregnation, which in the case of the former means the transference of pollen to the stigma. But the ancients believed that by grafting a shoot of one species to the stock of another, hybrids could be obtained that would produce fruit and seed bearing the intermediate characteristics of both species. Thus, for example, it is asserted¹¹ that by grafting an almond tree on a terebinth, it is possible to obtain the pistachio, a fruit which resembles the almond but belongs to a different, remote family. Graeco-Roman agricultural literature gives advice on how to produce new species by grafting different species of trees. This advice, which belongs to the province of agricultural folklore, penetrated into the *Aggadah*, the *Tosefta*, and the Jerusalem *Talmud* but Judah ha-Nasi, having apparently sifted these *halakhoth*, omitted them from the *Mishnah*.

The characteristics and the attributes of the seed determine the quality of the crop, a notion that is often applied metaphorically in the Bible to man¹². To this realm belongs the principle that 'a Jew, even though he sins, is still a Jew'¹³, that is, his actions do not preclude him from being considered one. Even the offspring of an apostate are regarded as Jews, for the negative characteristics acquired by a person because of environmental influences cannot change the characteristics of his offspring. Thus Jeremiah¹⁴ and Ezekiel¹⁵ already protested against those who declared: 'the fathers have eaten sour grapes, and the children's teeth are set on edge'. Even the positive characteristics and knowledge which a man acquires in his lifetime are not transmitted by heredity to his offspring: 'Why is it not usual for scholars to have sons who are scholars? That it might not be said, "Among them the *Torah* is inherited"¹⁶'. Hence everyone must start anew to learn the *Torah* and an occupation. Nor is it possible even by prayer to change the sex of the embryo in its mother's womb¹⁷.

On the other hand, the literature of the sages contains statements, according to which other factors and not only heredity are liable to determine the characteristics of the child. Thus the time of coition has an influence: those who have

sexual intercourse in the daytime have red-spotted children¹⁸; a woman who solicits her husband to the marital obligation will have sons who are scholars¹⁹; a child's characteristics and fate depend upon the day on, and the constellation under which it is born²⁰. The *Aggadah* tells that R. Johanan, who was famous for his beauty, would sit near the ritual bath for women, so that when they came from it they might look at him and have children as beautiful as himself²¹. The *Midrash* relates that when a white son was born to a black couple, Judah ha-Nasi explained to the husband that this was because his wife had gazed at white mirrors in their home²². By placing objects before a cow's eyes when it was being mated, a red heifer could be obtained²³.

The principle that characteristics acquired by an organism during its lifetime are likely to be transmitted by heredity to its progeny was current in the folklore and literature of the ancient peoples of Greece and Rome, and persisted in the theories of Darwin and Lamarck, according to whom evolution is the product of the transmission of acquired characteristics. Refuted by modern experimental science, these theories are contrary to the Mendelian laws, whose principle is that hereditary characteristics are stable and not liable to changes due to environmental factors.

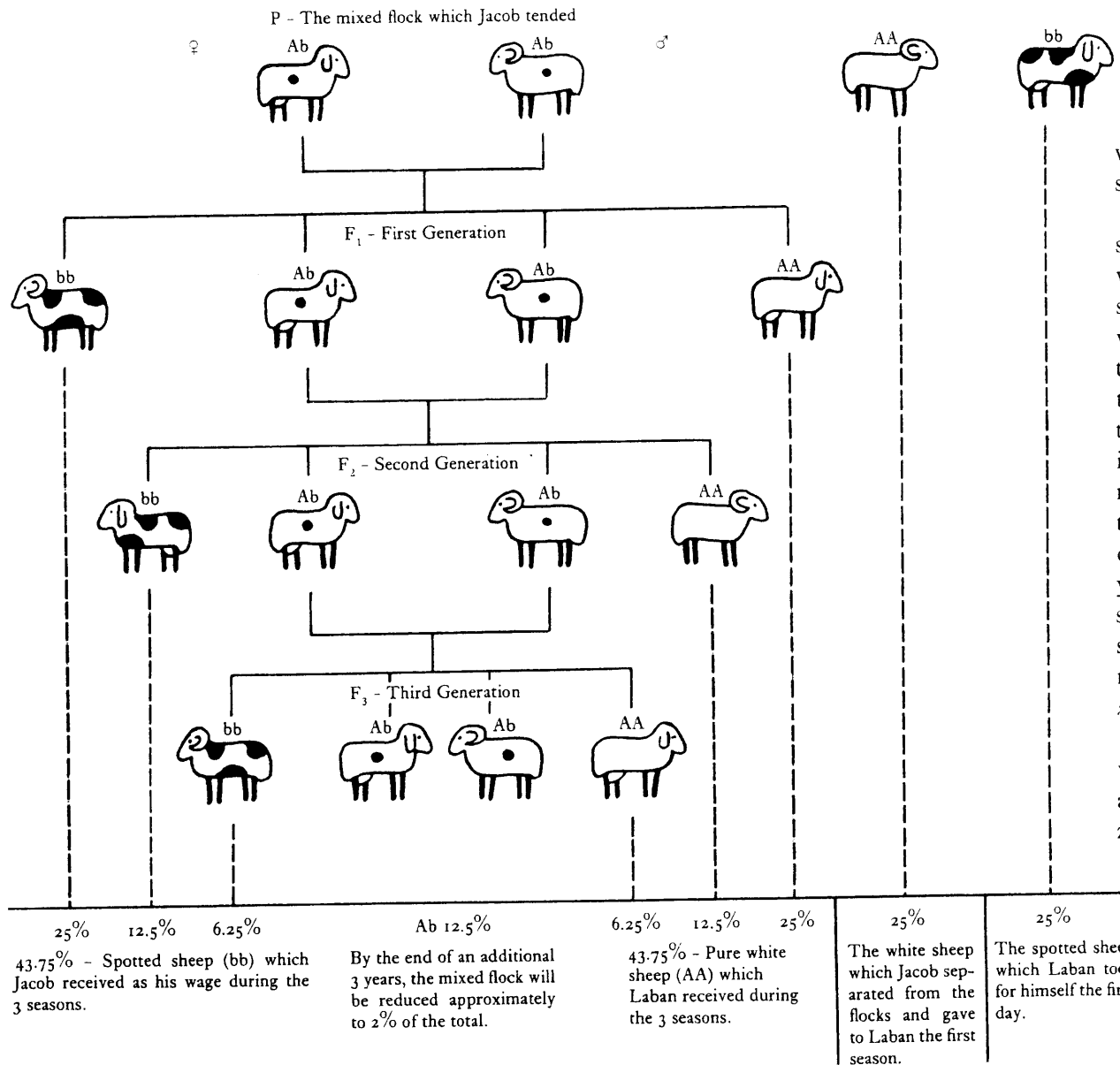
2. STREAKED, SPECKLED AND SPOTTED SHEEP

This problem of the relation between heredity and environment is to be found in the biblical account of what Jacob did with Laban's sheep²⁴. According to the accepted interpretation it was the rods, in which Jacob peeled white streaks and which he set 'over against the flocks', that led to the birth of sheep with different coloured skin²⁵. But this interpretation is entirely fallacious. From the biblical passage it emerges that the laws of heredity were revealed to Jacob when the angel of God, appearing to him, opened his eyes to a comprehension of the subject²⁶. On the basis of this assumption, the passage can be satisfactorily explained. Jacob suggested to Laban:

I will pass through all thy flock today, removing from thence every speckled and spotted one, and every dark one among the sheep, and the spotted and speckled among the goats; and of such shall be my hire²⁷.

The sheep in this region are usually white in the places where the wool grows, only about a quarter of them having brown spotted wool; while the goats usually have black hair, and only about a quarter of them have white or brown spots. The entirely white sheep, and the completely black goats, are designated as 'monochrome' and the spotted sheep and goats as 'spotted'. Jacob suggested that Laban separate from the monochrome sheep all the spotted ones and take them for himself, and he, Jacob, would tend only the monochrome ones. As his remuneration ('and of such shall be my hire'), he

Bifurcation in crossbreeding the offspring of pure white sheep (A) with brown spotted sheep (b). The pure white gene is dominant over the spotted.



would receive all the spotted young that would be born from the monochrome sheep and goats.

Laban readily fell in with this suggestion, assuming that the monochrome sheep would bear only a trifling percentage of spotted young, and such indeed would have been the case were it not that Jacob adopted a special method of selection, as will be explained later. Laban removed all the spotted sheep, which constituted 25 per cent of the entire flock, and put his sons in charge of them²⁸. For fear that there might be contact between these sheep and those tended by Jacob, he set the two flocks far apart from each other²⁹. In the flock tended by Jacob there were ostensibly only monochrome sheep. This was so in respect of phenotype, but as regards genotype a third of them were pure monochromes (*homozygotes*) and two-thirds *heterozygotes*, that is, they contained the gene of 'spottedness'. And since the gene of 'monochromeness' is dominant, all the sheep appeared monochrome. In order to obtain spotted young, Jacob had to see that only the heterozygotes were crossed among themselves, and these according to the laws of heredity bore 25 per cent spotted sheep, which became Jacob's property. But all this was on condition that the monochrome *heterozygotes* were not crossed with the monochrome *homozygotes*, from which only monochrome sheep would be born.

How he could distinguish between the heterozygotes and the homozygotes was revealed to Jacob in his dream by the angel: 'Lift up thine eyes, and see, all the he-goats which leap upon the flocks are streaked, speckled, and grizzled'.³⁰ Ostensibly, that is, all the he-goats were monochrome but in some

the characteristic of 'spottedness' was recessive. This characteristic could be detected by the phenomenon of the hybrid's excessive potency (hybrid vigor-heterosis), that is, the monochrome sheep carrying the genes of 'spottedness' conceived earlier than the *homozygotes*. Those that showed this hybrid vigour are called in the Pentateuch *mekusharoth* ('the stronger') and the others *'atufim* ('the feebler'). According to the biblical narrative, Jacob laid the peeled rods before 'the stronger' sheep that they might conceive, but not 'when the flock were feeble', that is, not before those that conceived later³¹, and the passage concludes: 'So the feebler were Laban's and the stronger Jacob's', that is, Jacob handed over to Laban all the *homozygote* monochromes which had not revealed *heterosis* – these in addition to the spotted ones which Laban had received when the flocks were divided. The peeled rods that Jacob laid before the conceiving sheep were intended only to pretend to Laban that he was following the usual procedure of shepherds (which is also done nowadays) whereas in point of fact he had adopted a method of selection unknown to Laban.

Accordingly, in the first season Jacob was left with 50 per cent of Laban's sheep. During the following seasons, extending over six years,³² he obtained from the sheep that he tended nearly 50 per cent spotted ones and Laban received about the same percentage. Hence Laban was left with a total of 75 per cent of all the sheep, while Jacob got 25 per cent of them. Actually Jacob got 50 per cent of the sheep he raised, for in the first year he gave Laban all the homozygotes. Such a result Laban could not have expected and no shepherd could have obtained it without a precise knowledge of the laws of heredity.

Genesis xxx-xxxi thus represents the earliest document on a practical familiarity with the laws of heredity and *heterosis*. The Bible gives a detailed account of all stages in this episode, perhaps to controvert the prevalent view that man can influence heredity by rods and similar objects. Another episode in the same chapter, that is, the incident of the *dudaim* (mandrakes)³³, is also apparently intended to emphasize that conception and birth are a divine gift and cannot be influenced by charms, such as the fruit of the mandrakes. And indeed the biblical passage stresses that it was Leah, who gave the mandrakes to Rachel, who became pregnant and bore a son, and not Rachel, who received them.

1. *T. Y. Kil.* 8, 31c and similarly in *Nid.* 31a
2. *Hul.* 69a
3. *ibid.*
4. *Gen.* 1:12
5. *Nid.* 31a
6. *Sifre Deut.* 306
7. *Kil.* 1, 1
8. *T. Y. Kil* 1, 1, 26d
9. *De alimentorum facultatibus* 1, 37
10. *Hexameron*, v
11. *T. Y. Kil* 1, 4, 27a
12. e.g., *Hos.* 10:20; *Prov.* 11:18; 22:8; *Job* 4:8
13. *Sanh* 44a
14. 31:29
15. 18:2
16. *Ned* 81a
17. *Ber* 9:3
18. *Ber* 59b
19. *Erub* 100b
20. *Shab* 156a
21. *Ber* 20a
22. *Gen R* 73
23. *A. Z.* 24a
24. *Gen.* 30:31-43
25. *Gen.* 30:37
26. *Gen.* 31:12
27. *Gen.* 30:32
28. 30:35
29. 30:36
30. *Gen.* 31:12
31. *Gen.* 30:41-42
32. 31:41
33. *Gen.* 30:14-17