42. Probability-theoretic Investigations on Inheritance. VIII$_3$. Further Discussions on Non-Paternity Problems.

By Yûsaku KOMATU.

Department of Mathematics, Tokyo Institute of Technology and
Department of Legal Medicine, Tokyo University.

(Comm. by T. FURUHATA, M.J.A., March 12, 1952.)

3. Sub-probability with respect to a type of child.

We now turn to the third standpoint stated at § 1, namely, the decomposition of whole probability of proving non-paternity into sub-probabilities with respect to a type of child.

Necessary components for the purpose have already been established. In fact, the table for $V(ij;hk)$ listed in § 2 of VII remains here also utile. The results which will anew be obtained in the present section are those derived by summing up the quantities $P(ij;hk)$ with respect to all the possible types A_{ij} of wife (mother of child), while, in (2.3) of VII, the summation has been extended over the types A_{hk} of child. We thus introduce here the quantity

$$R(ij)=\sum_{h,k} P(hk;ij), \tag{3.1}$$

the letters i, j, h, k being interchanged only for the sake of convenience.

First, in case of a homozygotic child A_{ii}, we obtain

$$\begin{aligned} R(ii)&=P(ii;ii)+\sum_{j\neq i} P(ij;ii) \\ &=p_i^3(1-p_i)^2+\sum_{j\neq i} p_i^2 p_j(1-p_i)^2 \\ &=p_i^2(1-p_i)^2. \end{aligned} \tag{3.2}$$

Next, in case of a heterozygotic child $A_{ij}(i\neq j)$, we obtain

$$\begin{aligned} R(ij)&=P(ii;ij)+P(jj;ij)+P(ij;ij)+\sum_{h\neq i,j}(P(ih;ij)+P(jh;ij)) \\ &=p_i^2p_j(1-p_j)^2+p_ip_j^2(1-p_i)^2+p_ip_j(p_i+p_j)(1-p_i-p_j)^2 \\ &\qquad +\sum_{h\neq i,j}(p_ip_jp_h(1-p_j)^2+p_ip_jp_h(1-p_i)^2) \\ &=p_ip_j(2-2(p_i+p_j)+p_i^2+p_j^2-4p_ip_j+3p_ip_j(p_i+p_j)). \end{aligned} \tag{3.3}$$

The partial sums corresponding to (3.1) to (3.3), (3.5) and (3.7) of VII now become

$$\sum_{i=1}^{m} P(ii;ii)=S_3-2S_4+S_5, \tag{3.4}$$

$$\sum_{i=1}^{m}\sum_{j\neq i}P(ij;ii)=S_2-3S_3+3S_4-S_5, \tag{3.5}$$

$$\sum_{i,j}{}'(P(ii;ij)+P(jj;ij))=S_2-S_3-2S_2^2+2S_4+S_2S_3-S_5, \tag{3.6}$$

$$\sum_{i,j}{}'P(ij;ij)=S_2-3S_3-2S_2^2+5S_4+3S_2S_3-4S_5, \tag{3.7}$$

$$\begin{aligned}&\sum_{i,j}{}'\sum_{h\neq i,j}(P(ih;ij)+P(jh;ij))\\ &\qquad=1-5S_2+7S_3+2S_2^2-6S_4-S_2S_3+2S_5.\end{aligned} \tag{3.8}$$

It will be quite evident that the total sum of (3.4) to (3.8) again implies just the whole probability (2.19).

On the other hand, we get, from (3.2) and (3.3),

$$\sum_{i=1}^{m}R(ii)=S_2-2S_3+S_4, \tag{3.9}$$

$$\sum_{i,j}{}'R(ij)=1-3S_2+3S_3-2S_2^2+S_4+3S_2S_3-3S_5. \tag{3.10}$$

The sum of both expressions (3.9) and (3.10) yields also the whole probability.

Now, the standpoint of the present section is rather in closer relation with the argument in the preceding chapter, than that in § 1. If a type of child is regarded as basis, it will be necessary to enumerate possible types of husband never producing a child of given type with his wife (its mother). The question becomes thus to determine the probability of mating which consists of a wife being mother of a given child and her husband not being father of the child. In the present case, the probability of deniable matings may, however, not be regarded as a simple product of general frequencies. In fact, since a type of child is preassigned, the probability of wife, i.e., mother of child, must rather be given by the probability a posteriori introduced in (1.28) of IV.

Given a child A_{ij}, the probability of such a mating that a wife A_{hk} is its mother but her husband A_{fg} is not its father, is thus equal to

$$\frac{\pi(hk;ij)}{\bar{A}_{ij}}\cdot\bar{A}_{fg}. \tag{3.11}$$

Hence, the probability of such a deniable mating in which the frequency of child is also taken into account is given by

$$\bar{A}_{ij}\frac{\pi(hk;ij)}{\bar{A}_{ij}}\bar{A}_{fg}=\pi(hk;ij)\bar{A}_{fg}; \tag{3.12}$$

a result which is also quite plausible. The standpoint of the preceding chapter consisted in summing up the quantities (3.12) over all the deniable types A_{fg} of husband, obtaining

$$P(hk;ij)=\sum_{f,g}\pi(hk;ij)\bar{A}_{fg}, \tag{3.13}$$

while that of § 1 consits in summing up (3.12) over all the inadmissible types A_{ij} of child, obtaining

$$W(hk;fg)=\sum_{i,j}\pi(hk;ij)\bar{A}_{fg}. \tag{3.14}$$

The quantity defined in (3.1) is nothing but the total sum of (3.13) over all the possible types A_{hk} of wife (mother of child):

$$R(ij)=\sum_{h,k}P(hk;ij)=\sum_{h,k,f,g}\pi(hk;ij)\bar{A}_{fg}. \tag{3.15}$$

The results contained in the present section may be tabulated as follows.

Child	Mother of child	Non-father of child	Prob. of triple-comb.	Sub-prob. against each child	Partial sum over mother-child comb.
A_{ii}	A_{ii}	$A_{kl}(k, l \neq i)$	$p_i^3(1-p_i)^2$	$p_i^2(1-p_i)^2$	$S_3-2S_4+S_5$
	A_{ij}	$A_{kl}(k, l \neq i)$	$p_i^2p_j(1-p_i)^2$		$S_2-3S_3+3S_4-S_5$
A_{ij}	A_{ii}	$A_{kl}(k, l \neq j)$	$p_i^2p_j(1-p_j)^2$		$\left\{\begin{array}{l}S_2-S_3-2S_2^2\\+2S_4+S_2S_3-S_5\end{array}\right.$
	A_{jj}	$A_{kl}(k, l \neq i)$	$p_ip_j^2(1-p_i)^2$		
	A_{ij}	$A_{kl}(k, l \neq i, j)$	$\left\{\begin{array}{l}p_ip_j(p_i+p_j)\\ \times(1-p_i-p_j)^2\end{array}\right.$	$\left\{\begin{array}{l}p_ip_j(2-2(p_i+p_j)\\+p_i^2+p_j^2-4p_ip_j\\+3p_ip_j(p_i+p_j))\end{array}\right.$	$\left\{\begin{array}{l}S_2-3S_3-2S_2^2\\+5S_4+3S_2S_3-4S_5\end{array}\right.$
	A_{ih}	$A_{kl}(k, l \neq j)$	$p_ip_jp_h(1-p_j)^2$		$\left\{\begin{array}{l}1-5S_2+7S_3+2S_2^2\\-6S_4-S_2S_3+2S_5\end{array}\right.$
	A_{jh}	$A_{kl}(k, l \neq i)$	$p_ip_jp_h(1-p_i)^2$		

The results discussed above concern exclusively genotypes. The corresponding results concerning phenotypes can be derived by taking an individual mode of inheritance into account. Of course, only the cases are then anew essential where recessive genes are existent, and, for instance, deniable types of non-fathers require to be considered correspondingly carefully.

43. *Influence of the Temperature of the Fluid Environment upon the Locomotion of Ascaris in the Glass Tube.*

By Takeo BANDO, Tatsushi ISHIZAKI, and Yoshito KOBAYASHI.
Department of Pharmacology, Faculty of Medicine, University of Tokyo.

(Comm. by S. KATSUNUMA, M.J.A., March 12, 1952.)

Although some studies (1, 2, 3) were performed hitherto concerning the optimal temperature of the solution for survival of ascaris tested in vitro, yet there remains another problem about the influence of the temperature of the fluid environment upon the locomotion of the worm as described by us in the previous report (4, 5).

1) The period of the movement influenced by changes in the temperature.—The period of the movement of ascaris was markedly influenced by changes in the temperature of the solution in which it was tested. If the temperature was raised, the period became shorter generally. But there was no significant difference between 32°C and 34°C, whereas differences between those and some other temperatures were significant (Fig. 1).

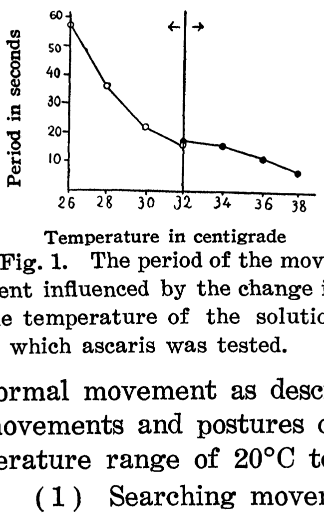

Fig. 1. The period of the movement influenced by the change in the temperature of the solution in which ascaris was tested.

2) Abnormal movements of the worm induced by changes in the temperature of the solution.—Beside the normal movement as described in detail already, several abnormal movements and postures of the worm-body took place in the temperature range of 20°C to 50°C.

(1) Searching movement of the head. The worm can be seen to make continuous movements with its head as if in search of something. This is more distinct during the period in standstill rather than in locomotion, especially in the solution maintained at a temperature near optimal. But this searching movement became more marked and severe when the environment for the worm was abnormally higher in temperature. When the tip of the head of the worm, in which its central nervous organ is localized, was removed, the searching movement of the head could no longer be observed, while the worm continued the same locomotion. This move-

ment of the head of the worm must be, therefore, one of the normal motor activities that is presumably necessary for the worm to push itself forwards without difficulty.

(2) Backward movement. The worm moved backwards and reversed the direction of its progression with the initial curvature starting in the fore part of the body. But the production of curvatures of the body was not as complete as in the ordinary movement, and the velocity was so slow that it may be inadequate to regard it as a proper retrograde locomotion of ascaris. This could be seen in the solution at such abnormally high temperatures as from 36°C to 46°C.

(3) Shape of an 'infinity sign' (∞). The worm changed the course of its locomotion so repeatedly that it took temporarily the shape of an infinity sign (∞). This came often in sight in the solution at every temperature above 30°C.

(4) Shape of a coil. The worm curled itself somewhat regularly just as a coil of wire. This appeared in the solution at abnormally high as well as low temperatures.

(5) Shivering at the head. This appeared distinctly only at its head in the case of temperature higher than 40°C.

(6) Streching the whole body at a standstill. The worm became to move irregularly and slightly, and then stretched itself motionless when it was extremely low in vitality near the end of life in a most unsuitable environment at high and low temperatures, such as 50°C and 20°C (Table 1).

Table 1

Changes in the type of movement of the worm exposed to a wide range of temperature. The temperature of the solution in which 8 worms were tested was raised from 32°C to 50°C, while 8 other worms were put in the solution whose temperature was lowered down gradually from 32°C to 20°C.

No. of ascaris / Temperature in centigrade	20	22	24	26	28	30	32	32	34	36	38	40	42	44	46	48	50
Normal locomotion	0	0	0	4	8	8	8	8	8	6	3	0	0	0	0	0	0
Searching movement: marked	0	0	0	0	0	0	0	0	0	1	2	3	5	1	1	0	0
Searching movement: moderate	0	0	0	3	6	8	8	8	8	7	6	4	2	6	3	1	0
Searching movement: mild	0	4	6	3	2	0	0	0	0	0	0	1	1	1	4	3	0
Backward movement	0	0	0	0	0	0	0	0	1	3	5	8	8	7	3	0	0
Shape of infinity sign	0	0	0	0	0	2	3	5	6	6	7	3	8	7	4	1	0
Shape of coil	3	4	6	3	2	2	1	1	0	3	2	1	3	6	4	3	1
Shivering at head	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	8	0
Stretching	0	0	3	4	0	0	0	0	0	0	0	1	1	2	4	7	0
Standstill	8	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	8

3) *Change in postures and movements of the worm kept under one of the several temperatures maintained throughout the observation in relation to the lapse of time.*—When the worm was observed in the solution maintained at 32°C until it came to the end of life, there appeared various abnormal movements, such as the shape of an infinity sign, the backward movement and the shape of a coil, after it had gone through the normal locomotion. The shape of a coil could be recognized in the relatively late stage of survival of the worm, while the searching movement of the head continued more or less throughout the test. The relatively high temperature range from 36°C to 46°C caused always the backward movement of the worm immediately after the exposure to the solution which was then followed by the complete standstill at such a high temperature as 44°C or 46°C; while some of the worms resumed the normal type of the locomotion with a much longer period than that of the original one, if it was tested in the solution at a somewhat lower temperature, i.e., at 40°C or 42°C. But, most of the worms showed a much shorter period of the movement in the locomotion than that in the ordinary one at 38°C, indicating the remarkable sensibility to the slight change in the temperature of the environment of the worm.

4) *Change in the sensibility to the temperature of the environment caused by deprivation of the central nervous organ of the worm.*— It was confirmed that, by deprivation of the head, there was almost no change in the type of the locomotion and the period of the movement in most of the worms, except the searching movement of the head, if it was tested in the solution at 32°C. 8 out of 10 worms which moved abnormally backwards by being kept in the solution maintained at 40°C resumed the normal forward locomotion after deprived of their heads, whereas the rest of them ceased their locomotion and curled themselves just in the shape of a coil. This happened regardless of whether the head was removed before or after exposure to such a high temperature. Now, it was recognized that the worm, which showed a much longer period of the movement, indicating much reduced vitality of it, after its central nervous organ had been deprived, was apt to take the shape of a coil of wire, if it was exposed to a high temperature. It is concluded that the head which contains the central nervous organ must be the most sensible part of the body to the change of the temperature.

5) *Survival time influenced by changes in the temperature in the solution.*—The survival time of the worm was the longest at 32°C and became shorter at any other temperature higher or lower (Fig. 2), and also the number of worms keeping on their locomotion was

largest in the solution maintained at 32°C when the temperature of the solution was raised as well as lowered gradually in a wide range (Table 2). All the worms were killed in a moment when they were put into the solution of 60°C (4). After an exposure within 30 minutes to the solution at 0°C, the worm began its movement again when transferred in the solution of the temperature near optimal. Female worms were a little more resistant to the higher temperature; on the contrary, male ones generally tolerated the lower temperature better.

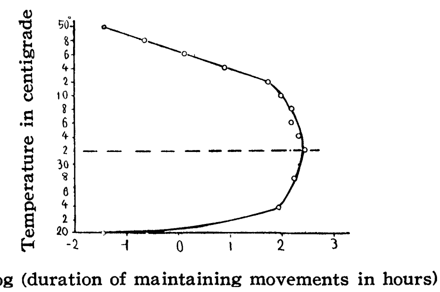

Fig. 2. The time-interval from the beginning of the test until the worm showed no spontaneous movement at various temperatures of the solution.

Table 2

Number of worms showing their locomotion in the solution maintained at various temperatures.

Temperature in contigrade	26	28	30	32	34	36	38
Locomotion	2	4	5	6	4	1	1
Standstill	6	4	3	2	4	7	7

Summary.

The period of the movement of ascaris was markedly influenced by changes in the temperature of the solution in which it was tested. If the temperature was raised, the period became shorter generally. It was also revealed that several abnormal movements and postures of the worm took place in the glass tube filled with the solution whose temperature was raised as well as lowered gradually over a wide range. Each of the postures differentiated from the original one was shown in a certain range of the temperature which was changed. But, when the worm was exposed to a relatively high temperature maintained throughout the survival time, it showed the normal type of the locomotion with a much longer period than that of the original one, indicating less active in vitality, after it had gone through several abnormal movements. The highest and lowest temperatures of the solution in which few worms could hardly move were 50°C and 20°C respectively. The time-interval from the beginning of the test until the worm ceased completely its movement, was measured in the solution of various temperatures. As far as ob-

served by us, it was longest at 32°C, and became shorter in living at any other temperature higher or lower. When the central nervous organ of the worm was cut away, the influence of the temperature upon the locomotion did not happen to be observed. It is subsequently concluded that the part of the body most sensible to the temperature may be identified as the central nervous organ placed in its head, and that the optimal temperature of the solution for our experiments concerning the locomotion of ascaris is 32°C.

References.

1) Küchenmeister: Arch. f. physiol. Heilkunde., **10**, 630 (1851).
2) von Schroeder, W.: Arch. f. experim. Pathol. u. Pharmakol., **19**, 290 (1885).
3) Lamson, P. D. and Brown, H. W.: Amer. Jour. Hyg., **23**, 85 (1936).
4) Kobayashi, Y. and Bando, T.: Proc. Japan Acad., **26**, 72 (1950).
5) Bando, T., Ishizaki T., and Kobayashi, Y.: Proc. Japan Acad., **27**, No. 10 (1951).