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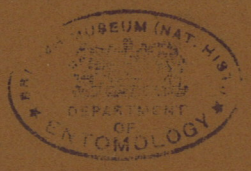
LOUSE CONTROL THROUGH TEXTILE FIBRE SIZE.



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LOUSE CONTROL THROUGH TEXTILE FIBRE SIZE.

By B. Hocking
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(Plates XII–XIV.)

During the last war, but before the advent of DDT, louse control was a problem in situations where the available chemicals were limited to the simplest materials such as naphthalene, sulphur and vinegar. In these circumstances, the possibility of making things uncomfortable for body lice, *Pediculus humanus humanus* L., by wearing clothing made of fibres too thick for them to get their claws around, seemed attractive. The idea lost its attraction when DDT became available, to regain it when lice resistant to DDT were reported (Hurlbut, Altman & Nibley, 1952; Eddy, 1953). Buxton (1947) cited Wigglesworth (1941) and Hase (1915) in showing the influence on lice of variation in fibre-thickness, but, at least within the size range of natural fibres, considered this of small importance. The recent appearance of many synthetic fibres (Larose, 1945), available in various diameters, encouraged this preliminary investigation of the possibilities of such an approach.

Size of Claw and Diameter of Host Hair.

If this idea were to be of value, then correlation between the size of the claws in the various species of lice and the diameter of the body hairs of their mammalian hosts would be expected. Hopkins (1943) found a correlation between coat texture of antelope host and genus of Trichodectid (Mallophaga) parasites, and discussed (1949) the influence of coat on host selection in both biting and sucking lice. A cursory examination of the claws of twelve species of Siphunculata available here indicated that their size was closely related to thickness of host hair; but the measurement of this correlation over a wide range of hair-diameters proved impossible, on account of the difference between the louse sexes and the different pairs of legs, the difficulty in selecting a suitable dimension of the claw for measurement, and the variation in diameter of host hair with the type of hair and the part of the body. The nature of the relationship is shown in Plate XII; hair-diameters in this are taken from Hausmann (1920), Toldt (1935) and Lochte (1938). In this connection it should be mentioned that most mammalian hair is slightly elliptical in section; where this is well marked, diameters shown represent the mean of the two axes of the ellipse. Arising out of these observations it was found that the claws of the front legs of males of *P. humanus* can only encompass the hind femora of the female at the notch behind the femoral spur (Nuttall, 1917) where they are a beautiful fit (fig. 1, d). This notch, difficult to see in a whole mount from dorsal aspect, has only rarely been figured.

It seems that the ability of the louse claw to become adapted to different diameters of host hair is limited at both ends of the range of these. Both at the extreme upper and lower limits of diameter of mammalian hair, the Sirenia and the Chiroptera (hair-diameter of dugong, 1177μ, of *Mormops*, 6·8μ; Hausmann, 1920), lice have been unable to succeed (Hopkins, 1949). Near both the upper and the lower limits, grip has become the function of the head; the elephant louse, *Haematomyzus elephantis* Piaget (Mallophaga), clearly employs the proboscis for this purpose. This structure is very well developed and strangely

reminiscent of the hypostome of a tick. Many of the Trichodectid Mallophaga on small rodents hold a host hair in a groove of appropriate width in the head with the hypognathous mandibles. The sparseness of the hair in the Sirenia and the elephants has undoubtedly been important too.

The Culture of Lice.

Lice, *Pediculus humanus humanus*, were reared on 1½-in. squares of black wool barathea stored in transparent plastic boxes $1\frac{3}{4} \times 1\frac{3}{4} \times \frac{3}{4}$ in. In the top and bottom of the boxes were $1\frac{3}{8}$-in. holes covered with silk chiffon cemented to the outside of the box. The boxes were worn by the author and volunteers during the day, held against various parts of the body by elastic bandages. At night they were left at room temperature. First-instar nymphs fed quite well through the chiffon, but in the early stages, when a population was being built up, it was found preferable to feed them directly on the skin. It was easier to keep track of the colourless unfed nymphs if the skin were first darkened by rubbing on a mixture of cosmetic lampblack and unguentum lyophilium (Anon., 1949).

About ten pairs of adult lice were maintained in each box. When many eggs had been laid, the lice were transferred to new barathea squares, and the squares carrying eggs were put in a desiccator. This contained a saturated solution of sodium chloride to keep the relative humidity at 76 per cent., and was held at a temperature of 85°F. Lice which were in use for experiments were fed directly

TABLE I.

The characteristics of the fabrics on which the grip and grab of lice were measured. (Diameters in microns.)

	Fabric	Fibre	Warp			Weft		
			Fibre diameter	Approx. thread diameter	No. of threads per cm.	Fibre diameter	Approx. thread diameter	No. of threads per cm.
1.	Drill (ironed)	Cotton	8–19	270	37	8–19	305	23
2.	Drill (worn)	Cotton	8–19	270	37	8–19	305	23
3.	Bolting cloth	Silk	9–15	75	50 (double threads)	9–15	75	50 (double threads)
4.	Barathea	Wool	13–32	210	28	13–32	450	40
5.	Tulle	Nylon	43–45	—	30	43–45	—	30
6.	Saran 60 × 60	Saran	127–135	—	23	127–135	—	23
7.	,, 120 × 56	,,	214–225	—	46	236–255* × 127–135	—	19
8.	,, 52 × 52	,,	214–225	—	20	214–225	—	20
9.	,, 90 × 40	,,	255–277	—	35	255–277	—	16
10.	,, Cellular	,,	378–418	—	10	378–418	—	10
11.	,, 8 × 8	,,	504–516	—	3	504–516	—	3

* Fibres flattened.

on the skin on the inside of the forearm for 15 minutes twice daily, beginning at 0900 hr. and 1700 hr.

Nymphs, especially the earlier stages, showed a reluctance to feed and a tendency to wander when placed directly on the skin of a person on whom they had not previously fed. For example, 12 to 20 individuals out of a batch of 50 would move 3 to 4 in. from the cloth square on which they were placed on the skin. This tendency was almost completely lost after the first feed on the fresh host.

The Fabrics tested.

In selecting fabrics for test, the objective was to include a wide range of fibre-diameter, extending above that which the claws appeared able to grasp, and to include both fibres conventionally used in clothing and new synthetic materials. Beyond this, little selection was possible; colour and weave were largely dictated by availability.

The 11 fabrics used are listed, with their principal characteristics, in Table I, and four of them are illustrated in Plate XIII. The fabrics are arranged in order of fibre-diameter and are numbered serially. These numbers are used in the other Tables and in fig. 1.

The Measurement of Grip.

The force with which lice could cling to the fabrics was measured with the equipment shown in Plate XIV, fig. 1. A fine silk thread was tied around the louse in between the last two pairs of legs using a slip knot. This was done just after a meal; no anaesthesia was then needed, and there was no undue constriction of the body at subsequent meals. When the knot had been adjusted to the required tightness it was sealed with a droplet of wax applied with an electrically heated nichrome wire loop.

The louse was placed in the centre of a square of the fabric which was clipped to a plastic stage, with a hole in the centre, on the rack and pinion movement from a binocular microscope. A loop on the other end of the thread was placed on the hook of a torsion balance reading to 1 g. by 2-mg. divisions. The rack and pinion movement was then used to bring the index of the torsion balance to zero, and to maintain its position there by compensating for the slight stretch in the thread and in the fabric as tension was applied. Tension was applied to the thread and increased at a uniform rate by engaging the clutch of a kymograph motor which was arranged so as to advance the arm of the torsion balance. Various rates of tension increase were tried and 28·8 dynes per second was found to give the most consistent results; all the data used were obtained at this rate. Electrical contacts were arranged so that when the louse released its hold, the arm of the torsion balance completed a circuit through a relay which switched off the kymograph motor. There was a small overrun, which was constant at any given rate. The tension in the thread at the time that the louse released its hold was obtained by subtracting this correction from the reading on the dial of the torsion balance.

At each series of tests, one louse specimen was used to obtain five readings on each fabric; the fabrics were taken in random order. No tests were made with nymphs; twelve females and six males of various ages were used; no louse was used for more than two sets of readings on any one day. A total of 150 readings was obtained on each fabric, 100 with females and 50 with males. The results are summarised in Table II and fig. 1.

A binocular microscope was arranged so that the lice could be closely observed while clinging to the fabric. It was found that if the fibres were too large to be encompassed by the claws the insects would sometimes obtain their hold by

TABLE II.

The force, in dynes, with which lice can grip various fabrics, and the percentage of lice grabbing the surface of fabrics inclined to the horizontal at different angles.

Fabric	Male grip	Female grip	Percentage of lice holding at inclinations of: 10°	20°	30°	40°	50°	60°	70°	80°	Percentage holding at all angles collectively ♂♂	♀♀ Nymphs	Overall percentage holding
1. Drill (ironed)	109 ± 25·3*	166 ± 17·4	94	71	47	20	16	0	0	0	24	32	35	31
2. Drill (worn)	186 ± 26·9	239 ± 25·7	97	72	40	23	30	17	10	7	25	31	54	35
3. Bolting cloth	315 ± 37·0	389 ± 25·7	100	83	40	33	16	10	7	3	34	36	40	37
4. Barathea	401 ± 22·1	376 ± 32·7	100	93	83	50	40	33	40	23	54	60	58	58
5. Tulle	355 ± 28·8	454 ± 34·0	100	83	53	30	11	5	5	0	31	31	39	34
6. Saran 60 × 60	192 ± 31·3	283 ± 14·7	97	73	33	7	10	7	3	0	20	34	33	29
7. ,, 120 × 56	185 ± 38·7	158 ± 14·4	80	37	20	7	3	0	0	0	13	16	26	18
8. ,, 52 × 52	142 ± 17·7	66 ± 5·38	90	57	30	10	3	0	0	0	19	25	28	24
9. ,, 90 × 40	39 ± 9·18	65 ± 8·50	97	57	47	17	3	0	0	0	18	31	34	28
10. ,, Cellular	43 ± 5·38	65 ± 5·80												
11. ,, 8 × 8	27 ± 2·53	55 ± 4·25												
Average, all materials	252	181									26	33	39	

* Mean ± standard error of the mean.

clasping the fibre with one or more pairs of legs if the weave were open enough to permit this. A note was made of the readings obtained when this grip was used; they were always much lower than those obtained on other fabrics when a claw grip was achieved.

A few tests were run with the louse in darkness, the stage being placed inside a box with the thread passing through a small hole in the top. Other tests were run with recently fed lice, with lice starved for 24 hours, with recently emerged lice (12 hr.), and with lice of two weeks' adult age. No differences due to these factors were discernible.

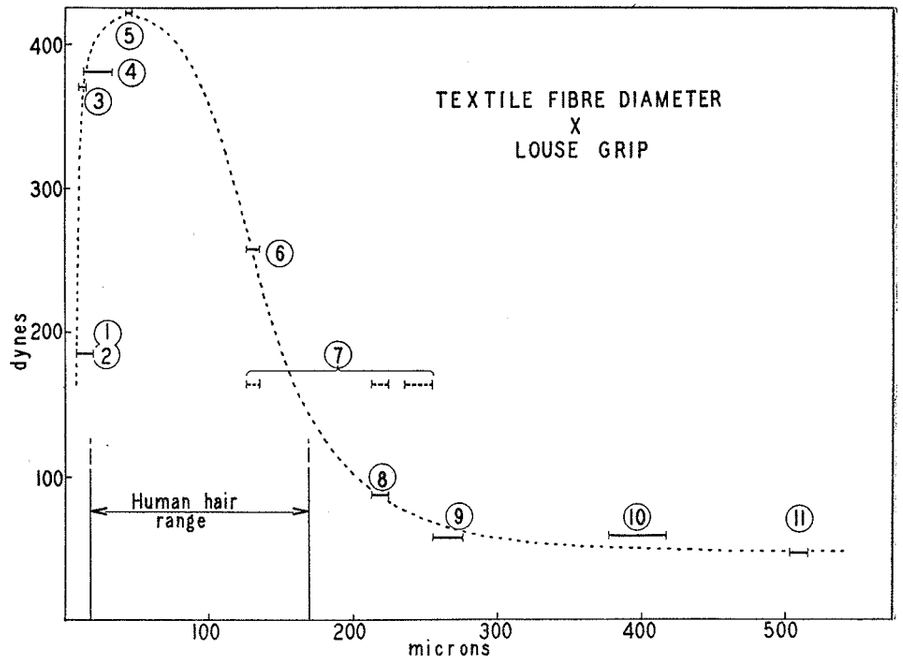

Fig. 1.—Textile fibre-diameter × louse grip.

In a few instances, both on barathea and on nylon tulle, female lice retained their hold up to the maximum capacity of the instrument, 981 dynes less the weight of the louse and harness. The average weight of female lice used was 2·27 mg., that of males 1·34 mg. The average weight of the harness was 0·25 mg. The average grip when a leg hold was used was 41 dynes.

The weft fibres of the 120 × 56 saran were ribbon-like, flattened in the plane of the fabric; individual readings obtained on this fabric were always higher when the claws gripped the edges of these fibres where the radius of curvature was less, lower when the thicker warp fibres were held.

When placed on the large-fibred fabrics, lice would grapple continuously for a hold sometimes for nearly a minute. Similar behaviour was shown when they were placed on smooth surfaces of glass or plastic. The activity was reminiscent of DDT jitters.

The Measurement of Grab.

The ability of lice to grab hold of a fabric surface, in relation to which they were in motion, was measured with the equipment shown in Plate XIV, fig. 2.

Lice were pushed over the curved polished edge of a lucite platform in such a manner that they fell freely for a distance of 5 cm. before landing on the stretched surface of the fabric under test. The fabric squares were clamped on a lower platform so that they could be rotated about a horizontal axis parallel to one edge and 5 cm. from it. This axis was vertically below the point at which the lice were pushed over the edge of the upper platform. The angle of inclination of the fabric platform was measured by means of a half-circle protractor across which a plumb line was suspended. In this way, whatever the inclination of the fabric, lice fell for a distance of five centimetres before contacting it, when, if they failed to hold at once, they slid, rolled, or bounced over it for a further 5 cm. before leaving its lower edge and falling freely into a dish placed below.

The 8 × 8 and the cellular saran fabrics were not used in these tests because of their open mesh. Adult males, adult females, and nymphs were tested separately on all of the other materials at every ten degrees of inclination from 10 to 80. Ten to 30 specimens of each stage and sex were dropped at each angle on each fabric. The results are given in Table II.

When lice were able to grab the fabric, this was nearly always at the point at which they first contacted it. Some tests with this equipment also were conducted in the dark, but no differences were discernible.

Oviposition.

Since fibres must be grasped by the gonopods for oviposition, fibre-diameter might be expected to influence this function too. During the studies on grip and grab, lice left in contact with the different fabrics overnight laid eggs on all of them except those made of saran, which were all of large-diameter fibres. In a preliminary test in which six gravid females were kept on 90 × 40 saran and wool barathea for alternate periods of 24 hours for six days, 23 eggs in all were laid on the barathea, none on the saran.

TABLE III.

The number of eggs laid by 20 gravid female lice in 24 hours on various fabrics.

Fabric	Test 1—Single discs		Test 2—Double discs		Mean no. of eggs laid
	Eggs laid	Mortality	Eggs laid	Mortality	
2. Drill (worn) ..	65	0	60	1	62·5
4. Barathea* ..	22	12	68	0	68
6. Saran 60 × 60	52	2	53	2	52·5
7. „ 120 × 56	41	2	36	1	38·5
8. „ 52 × 52	45	2	29	0	37
9. „ 90 × 40	28	3	32	1	30
0. Khaki wool cloth	76	0	79	0	77·5

* Cause of mortality in test 1 unknown; replaced by wool cloth (0) dyed black, in test 2.

By arrangement with W. C. McDuffie at the U.S.D.A. laboratory at Orlando, Florida, the following further tests were made by I. H. Gilbert. Twenty gravid female lice were placed on 1½-in. diameter discs of the fabrics in 50 ml. beakers and held at 82 to 85°F. and 70 per cent. R.H. for 24 hours. In a second test, two discs of the same fabric were used in each beaker. The only choice of

oviposition surface was between glass and the fabric. In each series, standard khaki wool cloth was included for comparison; the fibre-diameter in this ranged from 13 to 34 microns. Results are shown in Table III.

Discussion.

The diameter of human hair, according to Jackson & McMurtry (1912, p. 47) ranges from about 17 to 170 microns. This includes all kinds of hair, body hairs are rarely more than 100 microns thick, and average about 60 microns. The fibres for which the highest grip figures were obtained all had diameters within this range. Fibres over 200 microns in diameter do not appear to be very suitable for the attachment and locomotion of lice. Curves drawn as in fig. 1, but for each sex separately, show that the peak grip force by females is found at 43 microns fibre-diameter, that of males at 25 microns. Grip is apparently reduced on very small fibre-diameters as well as on large ones. This is not due to breakage of the fibres however; lice were never found to have the broken ends of fibres in their claws when pulled off fabrics. It may be supposed that the mechanical advantage of the unguitractor muscles is reduced when the claws have to be closed far enough to grip these fibres. The maximum grip forces recorded (in dynes) are about 440 times the weight of the louse (in mg.). The average grip which can be obtained with the leg hold is less than a tenth of that obtained on suitable fibres with the claws.

The ability of lice to grab hold of fabrics varies with fibre-diameter in a similar manner to grip, but rather less strongly. Weave has more influence here; the lowest figures for grab are those for the most closely woven saran material, 120 × 56, despite its relatively small fibre-diameter.

If the number of eggs laid is plotted against fibre-diameter (Table III), a curve of similar shape to that in fig. 1 can be drawn.

Fibres thick enough to present difficulties to lice do not seem likely to produce comfortable clothing; when a shirt made of 120 × 56 saran was worn next to the skin, the cut ends of fibres at the seams were the main source of discomfort. A more flexible fibre, in a suitable weave, might well prove satisfactory, and it would certainly be difficult for lice to colonise and maintain themselves on it. Possibly very fine fibres would also be an improvement over conventional materials if suitably spun and woven so that the threads did not provide easy claw holds. The value of starching and ironing drill in minimising the likelihood of picking up and carrying lice is clearly shown in Table II. Perhaps the most promising application for fabrics of unusual fibre diameter would be in outer garments for medical staff handling a typhus epidemic. The principle is used in reverse by eskimos who catch lice under the clothing by inserting a tuft of bear fur tied to a stick. After an appropriate interval the louse is withdrawn with the fur. The diameter of polar bear hair is very close to that of human hair.

There appears no doubt that hair-diameter is an important factor in host selection by lice. Perhaps louse-proof breeds of domestic animals can be developed by selecting for thicker or thinner hair, or even, in some instances, hairlessness. Allen & Dicke (1953) have shown that some cattle lice can be controlled by clipping.

Summary.

The possibility of controlling the human body louse, *Pediculus humanus humanus* L., through the development of clothing which is inimical to it on physical rather than chemical grounds was investigated. Claw size in lice was shown to be related to diameter of host hair. The grip force of lice on fabrics made of fibres of various diameters and compositions, some spun and some unspun, and of various weaves largely dictated by availability, was measured with an apparatus of which the essential parts were a torsion balance and a kymograph

motor. The force was found to be a maximum at fibre-diameters approximating that of human hair. The ability of lice to grab hold of a fabric when dropped on to an inclined surface of it was also measured and found to vary with fibre-diameter in a similar manner to grip, but less strongly. The number of eggs laid on fabrics when no choice was offered was also found to vary with fibre-diameter in a similar manner. While this physical method of louse control is not promising for immediate practical application, it has possibilities which may be enhanced by developments in textile technology.

Acknowledgements.

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References.

Anon. (1949). Canadian formulary, 1949.

Allen, N. N. & Dicke, R. J. (1953). Cattle lice control by clipping.—J. econ. Ent., **45,** pp. 970–973.

Buxton, P. A. (1947). The louse.—164 pp. London, Arnold.

Eddy, G. W. (1953). Effectiveness of certain insecticides against DDT-resistant body lice in Korea.—J. econ. Ent., **45,** pp. 1043–1051.

Hase, A. (1915). Beiträge zu einer Biologie der Kleiderlaus (*Pediculus corporis* de Geer = *vestimenti* Nitzsch).—Z. angew. Ent., **2,** pp. 265–359.

Hausmann, L. A. (1920). Structural characteristics of the hair of mammals.—Amer. Nat., **54,** pp. 496–523.

Hopkins, G. H. E. (1943). Notes on Trichodectidae (Mallophaga).—Rev. brasil. Biol., **3,** pp. 11–28.

Hopkins, G. H. E. (1949). The host-associations of the lice of mammals.—Proc. zool. Soc. Lond., **119,** pp. 387–604.

Hurlbut, H. S., Altman, R. M. & Nibley jr., C. (1952). DDT resistance in Korean body lice.—Science, **115,** pp. 11–12.

Jackson, G. T. & McMurtry, C. W. (1912). Diseases of the hair.—366 pp. New York.

Larose, P. (1945). Newer fibres.—Canad. Chem. Process Ind., **29,** pp. 476–479.

Lochte, T. (1938). Atlas der menschlichen und tierischen Haare.—306 pp. Leipzig, Schops.

Nuttall, G. H. F. (1917). Studies on *Pediculus*. I. The copulatory apparatus and the process of copulation in *Pediculus humanus*.—Parasitology, **9,** pp. 293–324.

Toldt, K. (1935). Aufbau und natürliche Färbung des Haarkleides der Wildsäugetiere.—291 pp. Leipzig.

Wigglesworth, V. B. (1941). The sensory physiology of the human louse *Pediculus humanus corporis* De Geer (Anoplura).—Parasitology, **33,** pp. 67–109.

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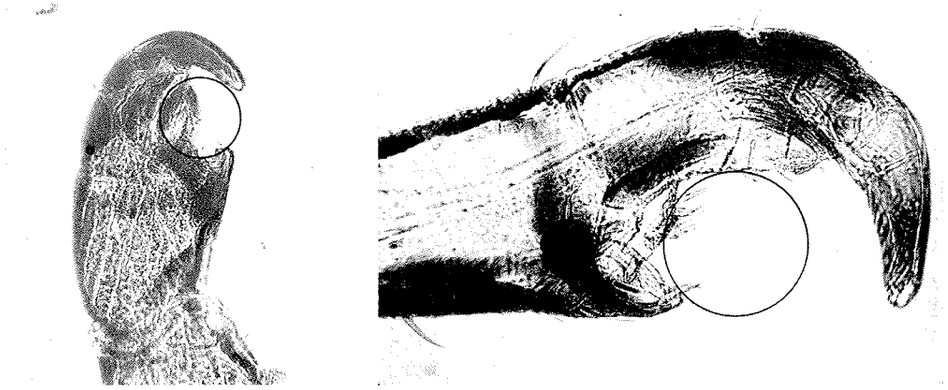

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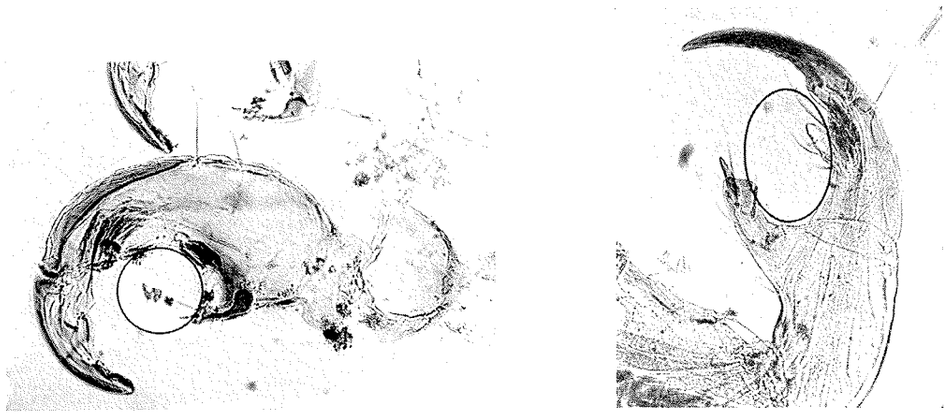
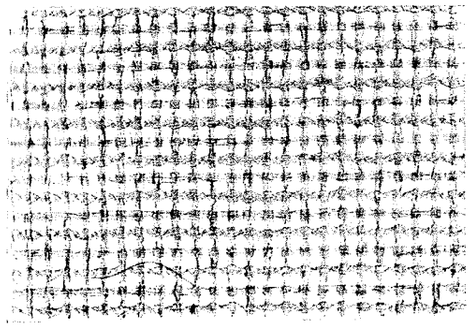


(c) (d)

The relationship between size of louse claw and diameter of host hair. The inscribed circles represent the average hair-diameter of the host-animal. In (c) this is the diameter of pubic, axillary, eyelash and beard hairs. The ellipse in (d) represents the size of the hind femur of the female at the notch behind the femoral spur. All are × 100.

(a) *Haematopinus asini* (L.) ♀, mesothoracic foot; (b) *Haematopinus suis* (L.) ♀, prothoracic foot; (c) *Phthirus pubis* (L.) ♀, metathoracic foot; (d) *Pediculus humanus* (L.) ♂, prothoracic foot.



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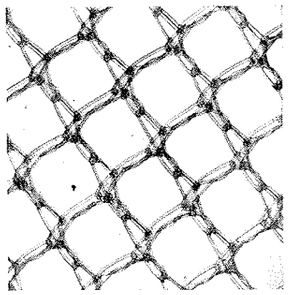

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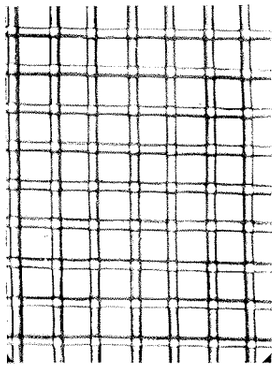
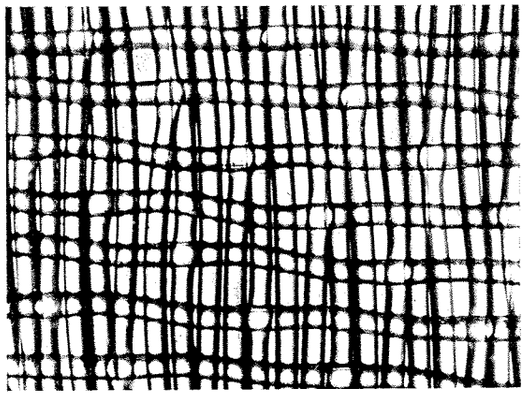


(c)



(d)

Four of the fabrics tested (× 12½).

(a) Silk bolting cloth; (b) nylon tulle;
(c) 60 × 60 saran; (d) 90 × 40 saran.

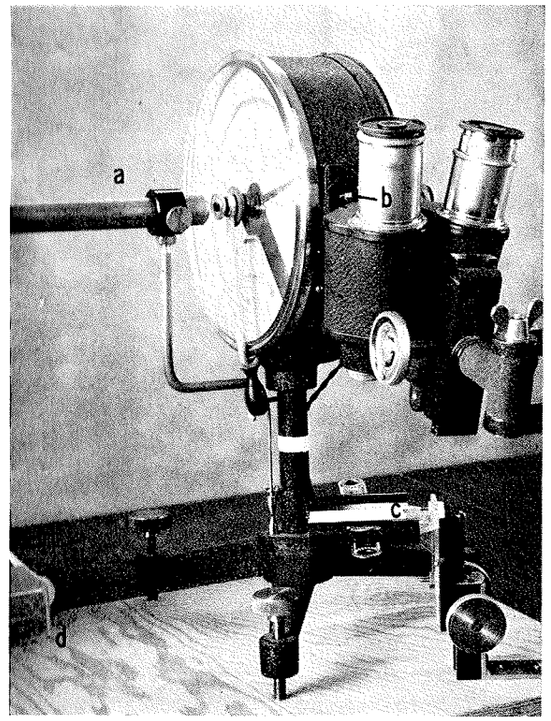


FIG. 1. Equipment used for the measurement of grip. (a) Kymograph shaft with arm operating lever of torsion balance; (b) torsion balance hook from which lice were suspended; (c) fabric sample clipped to stage on rack and pinion; (d) relay to switch off kymograph.

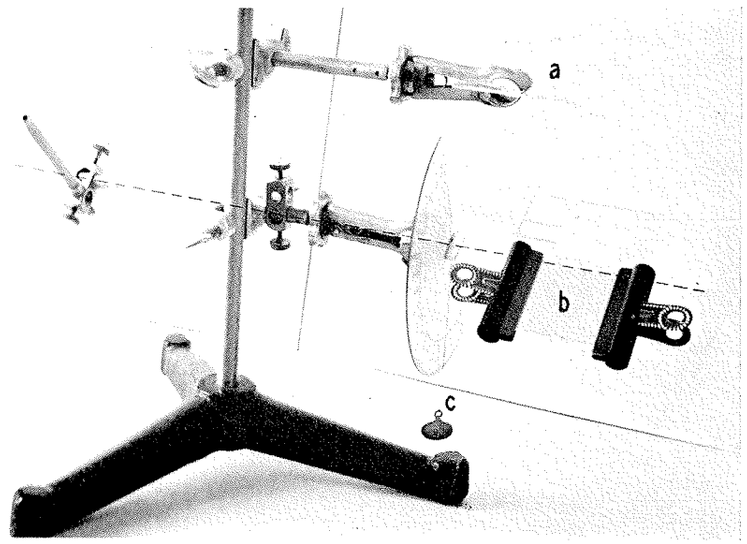


FIG. 2. Equipment used for the measurement of grab. (a) Lucite platform from which lice were pushed; (b) fabric sample clipped to stage rotating about axis shown by broken line; (c) plumb line on half-circle protractor.