as greater than 90°, *i.e.* directed upwards to the left, but where the anatomical axis is distinctly less than 90°, *i.e.* directed downwards to the left.]

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Corrigenda in Part I, 'Roy. Soc. Proc.,' B, vol. 86.

Page 512. In the second line of the footnote tan = *should read* tan $\alpha$ =.

Page 514. Last line, tan $\alpha = \frac{R-L}{R+L}$ *should read* tan $\alpha = 2\frac{R-L}{R+L}$.

Page 520. The record of the right superior lead is placed upside down. The first ventricular wave is actually negative.

Page 525. The numbers 36 and 47 in the last column (15th and 16th from bottom) should be transposed.

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## *On the Relation between the Thymus and the Generative Organs and the Influence of these Organs upon Growth.*

By E. T. Halnan and F. H. A. Marshall. (With a Note by G. Udny Yule.)

(Communicated by Prof. J. N. Langley, F.R.S. Received April 4,—Read June 18, 1914.)

Calzolari was the first to show that in castrated male animals the absolute weight of the thymus is larger than that of the same gland in normal animals. The experiments were made upon six rabbits, which were castrated when between one and three months old and killed at various periods afterwards up to nine months, each rabbit being compared with a control. Subsequently Henderson carried out a statistical investigation upon the weight of the thymus in cattle, and showed that in these animals castration caused a persistent growth and a retarded atrophy of the gland. Henderson also records two experiments upon guinea-pigs by Noël Paton, and the results of these are confirmatory of the observations upon cattle.

The possible reciprocal action of the thymus upon the testis was investigated by Noël Paton, who removed the former organ from 24 young guinea-pigs and killed them when they attained weights varying from 115 to 355 grm. These animals were compared with 23 normal guinea-pigs kept as controls. The conclusion reached was that in guinea-pigs below 300 grm. (*i.e.*, prior to the time when the thymus usually atrophies) thymectomy is followed by a more rapid growth of the testes. In guinea-pigs above 300 grm. Paton found that the difference in weight of the testes in thymusless and normal animals was not manifest. The figures upon

which these conclusions are based are dealt with statistically in an appendix to this paper by Mr. G. Udny Yule.

Noël Paton's conclusions have been challenged by Soli, who worked upon guinea-pigs and upon fowls. The guinea-pigs, except in the case of two pairs, were killed when weighing considerably over 300 grm., so that the results have no bearing upon Paton's assertion that in guinea-pigs below that weight thymusless animals tend to have larger testes than normal individuals. In the two pairs killed below 300 grm. the testes of the operated guinea-pigs were slightly lighter than those of the control animals. In the experiments upon fowls Soli found that in two cases the thymusless birds had heavier testes than the controls, but in 11 cases the testes of the operated individuals were lighter than those of the unoperated. Paton, however, points out that in certain of these the rate of growth was below the normal, and that the small size of the testes might have been due to inferior nutrition. Soli found that castration produced hypertrophy of the thymus or arrested atrophy in that organ. In the unoperated birds the average weight of the thymus was 0·6 grm. to each kilogramme of body weight, whereas in the capons its weight was 1·16 grm. to each kilogramme of body weight.

Gellin, Klose and Vogt, Marrassini, and Squadrini have also found that castration tends to enlargement of the thymus, or arrests the normal involution of the gland.

As a result of a further series of experiments, Paton has concluded that the thymus and the testis do not act antagonistically to one another, but that each organ has a stimulating influence upon growth, the one organ compensating for the removal of the other by undergoing hypertrophy. Paton found that castration alone without thymectomy had no effect upon the growth of young guinea-pigs, neither had thymectomy alone any influence upon the rate of growth. On the other hand, castration and thymectomy performed simultaneously in very young guinea-pigs was found to check growth. Considered in the light of our experiments to be described below we are of opinion that this effect may have been consequent upon the double operation, which very possibly lowered the resistance of the animals towards disease. Paton describes further experiments showing that in six castrated males and four castrated females the average weight of the thymus was greater than in control animals.

Basch, and also Klose and Vogt, describe extirpation of the thymus in dogs as producing a softening of the bones or retarding the growth of the bony tissues, besides causing other pathological phenomena. Similar changes resulting from thymectomy are described by Matti. Soli also has confirmed

these results for rabbits, but failed to confirm them for guinea-pigs, in which thymectomy is a simple operation. It is not improbable, therefore, that the inhibitory effects of the growth observed by Basch and others were merely post-operative, since they only occurred when the operation of thymectomy was a severe one.

Gudernatsch states that tadpoles fed upon thymus extract grew to an abnormal size and postponed undergoing metamorphosis. In some cases they did not change into frogs at all, but remained as giant tadpoles.

Stotsenburg, working upon the effect of ovariotomy on the growth of albino rats, found that this operation caused an increased rate of growth. This appeared to be the case not only after the age of sexual maturity was reached, but prior to the attainment of this age, since the removal of the ovaries appeared to induce an accelerating effect forthwith.

Lastly, Miss Hewer in a recent paper states that it is possible to induce a hyperthymic condition in rats by feeding these animals upon fresh thymus or upon thymus tabloids, and that this condition is accompanied by partial or complete sterility, the spermatogenetic tissue in the testes ceasing to be active or even undergoing atrophy. It is to be noted that these results are directly contrary to Paton's theory of a compensatory mechanism between the thymus and the testis.

*Record of Experiments with Guinea-pigs.*

The experiments described below were undertaken to put on a more quantitative basis the results obtained by Noël Paton in a previous paper, and form, with a few minor differences, a repetition of his work on the subject.

In the control thymectomies (pseudo-thymectomies) the thymus glands were exposed without being removed, and the neck afterwards sewn up in the usual way so as to make the operation resemble as nearly as possible an actual thymectomy. In the vasectomy experiments a portion of each vas deferens was removed, but the vascular supply of the testes was not interfered with.

The guinea-pigs were housed in roomy wire cages and given a liberal diet of oats, bran, and roots, varied occasionally with green food as circumstances permitted. The normal animals were housed in the same cages as the experimental ones, thus ensuring uniformity of external conditions for both sets of animals. With the exception of one experiment all the animals used were males.

Experiment 1: *Effect of the Removal of the Testes upon the Weight of the Thymus and the Growth of the Animal.*—In this experiment, 12 male guinea-

pigs were used. The experiment started on December 20, 1912. On February 7 the testes from six guinea-pigs were removed. On March 4 the thymuses of the entire set were extirpated. The animals were killed on May 9. The number of animals taken was too few to establish any possible growth effects due to removal of the thymuses and testes. The animals retaining the testes grew less in the later stages of the experiment, this possibly being due to the castration effect on growth observable in all castrated adult animals. With regard to the effect on the thymus, small though the number of animals is, the evidence is quite clear. Moreover, the fact that the animals castrated had all attained puberty before castration took place shows that the arrested atrophy and subsequent hypertrophy of the thymus cannot be explained by Paton's theory.

| Animal No. | Days after first weighing. | | | | Weight of thymus. |
|---|---|---|---|---|---|
| | 0. | 49. | 74. | 140. | |
| | | | Control Animals. | | |
| | grm. | grm. | grm. | grm. | grm. |
| 1 | 237 | 355 | 475 | 580 | 0·276 |
| 2 | 192 | 335 | 354 | — | 0·342 |
| 3 | 215 | 358 | 442 | 497 | 0·370 |
| 4 | 214 | 342 | 452 | 617 | 0·337 |
| 5 | 202 | 357 | 377 | 588 | 0·400 |
| Average— | | | | | |
| 4 animals ..... | — | — | 436 | 570 | |
| 5 „ ..... | 212 | 349 | 420 | | 0·345 |
| | | | Operated Animals. | | |
| 1 | 212 | 355 | 402 | 615 | 0·430 |
| 2 | 240 | 400 | 470 | 682 | 0·395 |
| 3 | 184 | 345 | 375 | 567 | 0·470 |
| 4 | 187 | 360 | 380 | 610 | 0·564 |
| 5 | 225 | 375 | 447 | 674 | 0·680 |
| Average..... | 209 | 367 | 415 | 629 | 0·508 |

Experiment 2 (figs. 1, 2, and 3): *Effect of Removal of the Testes on the Weight of the Thymus, of Removal of the Thymus on the Weight of the Testes, and upon the Growth of the Animal.*—This set contained 10 normal animals, 7 castrated, and 6 thymectomised. The animals were operated upon on February 24–27, and first collectively weighed on March 4. On May 9 the experiment terminated.

Reference to the data below shows that thymectomy has no effect upon growth, and that castration has little, if any, effect.

| Animal No. | Days after first weighing. | | Weight when killed. | Weight of testes + epididymes. | Weight of thymus. |
|---|---|---|---|---|---|
| | 0. | 63. | | | |
| | | | Control Animals. | | |
| | grm. | grm. | grm. | grm. | grm. |
| 1 | 202 | 349 | 375 | 1·25 | 0·253 |
| 2 | 157 | 365 | 380 | 1·43 | 0·395 |
| 3 | 164 | 385 | 420 | 2·05 | 0·392 |
| 4 | 182 | 310 | 320 | 1·02 | 0·197 |
| 5 | 127 | 275 | 290 | 0·376 | 0·390 |
| 6 | 170 | 412 | 420 | 1·67 | 0·350 |
| 7 | 180 | 395 | 410 | 2·08 | 0·380 |
| 8 | 185 | 410 | 425 | 1·82 | 0·300 |
| 9 | 221 | 452 | 470 | 2·38 | 0·395 |
| 10 | 191 | 452 | 468 | 2·43 | 0·390 |
| Average..... | 168 | 380 | 398 | 1·651 | 0·344 |
| | | | Castrated Animals. | | |
| 1 | 214 | 401 | 430 | — | 0·580 |
| 2 | 211 | 405 | 420 | — | 0·750 |
| 3 | 155 | 320 | 330 | — | 0·405 |
| 4 | 185 | 377 | 423 | — | 0·507 |
| 5 | 235 | 462 | 485 | — | 0·680 |
| 6 | 220 | 435 | 470 | — | 0·710 |
| 7 | 204 | 292 | 335 | — | 0·416 |
| Average..... | 203 | 385 | 413 | — | 0·578 |
| | | | Thymectomised Animals. | | |
| 1 | 135 | 440 | 450 | 2·185 | |
| 2 | 154 | 395 | 410 | 1·560 | |
| 3 | 154 | 315 | 325 | 1·200 | |
| 4 | 167 | 384 | 390 | 1·705 | |
| 5 | 142 | 347 | 355 | 0·835 | |
| 6 | 183 | 394 | 400 | 1·260 | |
| Average..... | 156 | 379 | 388 | 1·457 | |

Experiment 3 (fig. 1): *Effect of the Removal of the Testes on the Weight of the Thymus and the Growth of the Animal.*—This set contained originally 7 castrated and 9 normal animals, but owing to deaths only 4 castrated and 6 normals are recorded. The experiment commenced on the day of operation, March 17, and finished on June 24. Here castration seems to have had a positive effect upon growth, but the number of castrated animals (4) indicates the tentative nature of this result. As in Experiments 1 and 2 the effect of castration on the weight of the thymus is well marked.

| Animal No. | Days after first weighing. | | Weight of testes + epididymes. | Weight of thymus. |
|---|---|---|---|---|
| | 0. | 96. | | |
| | | Control Animals. | | |
| | grm. | grm. | grm. | grm. |
| 1 | 93 | 283 | 1·225 | 0·190 |
| 2 | 109 | 322 | 1·235 | 0·265 |
| 3 | 107 | 285 | 0·870 | 0·175 |
| 4 | 165 | 420 | 2·100 | 0·295 |
| 5 | 109 | 336 | 2·154 | 0·217 |
| 6 | 165 | 390 | 1·750 | 0·275 |
| Average ..... | 124 | 339 | 1·556 | 0·246 |
| | | Castrated Animals. | | |
| 1 | 148 | 412 | — | 0·610 |
| 2 | 140 | 346 | — | 0·452 |
| 3 | 111 | 372 | — | 0·430 |
| 4 | 124 | 391 | — | 0·540 |
| Average..... | 131 | 380 | — | 0·508 |

Experiment 4 (fig. 1): *Effect of the Removal of the Testes on the Weight of the Thymus and on the Growth of the Animal.*—To annul the operative effect the control animals were vasectomised. The experiment started on May 28 and finished on August 1 with 6 vasectomised and 5 castrated animals. The evidence in this experiment with regard to growth is contradictory to Experiment 3.

| Animal No. | Days after first weighing. | | Weight of thymus. |
|---|---|---|---|
| | 0. | 65. | |
| **Vasectomised Animals.** | | | |
| | grm. | grm. | grm. |
| 1 | 245 | 387 | 0·433 |
| 2 | 230 | 424 | 0·400 |
| 3 | 268 | 467 | 0·500 |
| 4 | 173 | 282 | 0·254 |
| 5 | 203 | 373 | 0·300 |
| 6 | 170 | 400 | 0·393 |
| Average..... | 215 | 389 | 0·380 |
| **Castrated Animals.** | | | |
| 1 | 243 | 330 | 0·573 |
| 2 | 280 | 405 | 0·607 |
| 3 | 210 | 353 | 0·738 |
| 4 | 147 | 320 | 0·545 |
| 5 | 157 | 336 | 0·614 |
| Average..... | 207 | 349 | 0·615 |

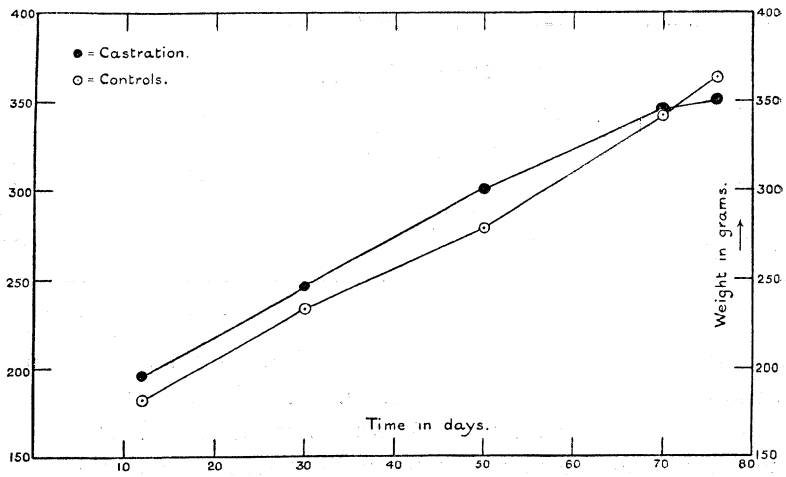


FIG. 1.—Effect of Castration on the Growth of Guinea-pigs.

(The curves are formed from the averages of the individuals of Experiments 2, 3, and 4.)

Experiment 5 (fig. 2): *Effect of the Removal of the Thymus on the Weight of the Testes and on the Growth of the Animal.*—To annul the operative effect the control animals were pseudo-thymectomised. The experiment started on May 27 and finished on July 8. There were 7 thymectomised animals and 6 pseudo-thymectomised in this set. The results obtained support the contention that thymectomy has no effect upon growth.

| Animal No. | Weight, May 27. | Weight after 42 days. | Weight of testes + epididymes. | Weight of thymus. |
|---|---|---|---|---|
| | | Control Animals. | | |
| | grm. | grm. | grm. | grm. |
| 1 | 210 | 325 | 1·420 | 0·325 |
| 2 | 177 | 316 | 1·155 | 0·510 |
| 3 | 190 | 267 | 0·610 | 0·315 |
| 4 | 151 | 238 | 0·470 | 0·235 |
| 5 | 162 | 290 | 1·012 | 0·320 |
| 6 | 190 | 338 | 1·380 | 0·283 |
| Average ..... | 180 | 296 | 1·008 | 0·331 |
| | | Thymectomised Animals. | | |
| 1 | 141 | 265 | 0·770 | |
| 2 | 227 | 307 | 1·112 | |
| 3 | 128 | 238 | 0·313 | |
| 4 | 153 | 257 | 0·574 | |
| 5 | 197 | 287 | 0·880 | |
| 6 | 150 | 245 | 0·527 | |
| 7 | 187 | 330 | 1·363 | |
| Average ..... | 169 | 276 | 0·791 | |

Experiment 6 (fig. 2): *Effect of the Removal of Thymus on the Weight of the Testes and on the Growth of the Animal.*—Nine normal animals and 14 thymectomised were used in this set. The operations were performed June 19–26. The experiment started on July 1 and ended on July 25. The evidence supports Experiment 5 with regard to growth. The effect on the testes is here in accordance with Noël Paton's results.

| Animal No. | Weight, July 1. | Weight after 24 days. | Weight when killed. | Weight of testes. | Weight of thymus. |
|---|---|---|---|---|---|
| | | | Control Animals. | | |
| | grm. | grm. | grm. | grm. | grm. |
| 1 | 133 | 187 | 200 | 0·320 | 0·277 |
| 2 | 213 | 317 | 322 | 1·250 | 0·410 |
| 3 | 201 | 267 | 272 | 1·120 | 0·322 |
| 4 | 151 | 245 | 252 | 0·676 | 0·350 |
| 5 | 136 | 193 | 207 | 0·320 | 0·320 |
| 6 | 171 | 245 | 235 | 0·620 | 0·408 |
| 7 | 226 | 316 | 340 | 1·125 | 0·480 |
| 8 | 170 | 268 | 307 | 0·970 | 0·506 |
| 9 | 166 | 252 | 240 | 0·633 | 0·460 |
| Average..... | 174 | 254 | 264 | 0·781 | 0·392 |
| | | | Thymectomised Animals. | | |
| 1 | 233 | 347 | 352 | 1·43 | |
| 2 | 156 | 219 | 221 | 0·454 | |
| 3 | 238 | 358 | 380 | 1·800 | |
| 4 | 168 | 226 | 212 | 0·425 | |
| 5 | 167 | 215 | 235 | 0·580 | |
| 6 | 201 | 260 | 245 | 0·930 | |
| 7 | 163 | 233 | 215 | 0·620 | |
| 8 | 205 | 296 | 300 | 1·170 | |
| 9 | 157 | 238 | 258 | 0·623 | |
| 10 | 197 | 301 | 310 | 1·450 | |
| 11 | 225 | 316 | 364 | 1·702 | |
| 12 | 205 | 256 | 237 | 0·835 | |
| 13 | 152 | 230 | 265 | 0·640 | |
| 14 | 158 | 234 | 257 | 0·630 | |
| Average..... | 187 | 266 | 275 | 0·949 | |

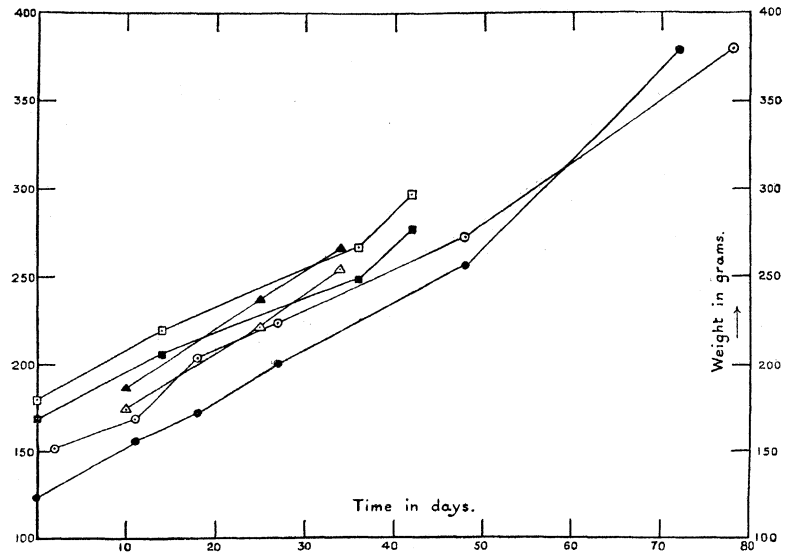


FIG. 2.—Effect of the Removal of the Thymus on the Growth of Guinea-pigs.

(The squares represent the averages of Experiment 5, the triangles Experiment 6, and the circles Experiment 2. In all cases the blacked figures represent the operated animals.)

Experiment 7 (fig. 3): *Effect of the Simultaneous Removal of the Testes and Thymus on the Growth of the Animal.*—This experiment was undertaken to investigate the effect of castration and thymectomy together on growth. In order to annul the operative effect the controls were vasectomised and pseudo-thymectomised. The experiment commenced with 9 animals, 4 operated, 5 controls, on July 16, and with 16 others (8 a side) on July 25. Reference to the protocol will show that this double operation has no effect upon the growth of guinea-pigs, a result directly contrary to that of Noël Paton.

Set 1.

| Animal No. | Weight, July 16. | Weight after— | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 9 days. | 37 days. | 75 days. | 86 days. | 101 days. | 125 days. | 150 days. | 177 days. |
| **Control Animals.** | | | | | | | | | |
| | grm. | grm. | grm. | grm. | grm. | grm. | grm. | grm. | grm. |
| 1 | 180 | 210 | 306 | 342 | 338 | 357 | 437 | 542 | 607 |
| 2 | 178 | 202 | 270 | 290 | 265 | 292 | 328 | 433 | 460 |
| 3 | 185 | 216 | 300 | 372 | 370 | 402 | 442 | 543 | 582 |
| 4 | 192 | 220 | 301 | 340 | 340 | 347 | 397 | 489 | 509 |
| 5 | 105 | 139 | 237 | 286 | 285 | 317 | 383 | 455 | 485 |
| Average ..... | 168 | 197 | 283 | 326 | 319 | 343 | 397 | 492 | 528 |
| **Operated Animals.** | | | | | | | | | |
| 1 | 186 | 215 | 280 | 335 | 344 | 360 | 375 | 445 | 472 |
| 2 | 195 | 221 | 285 | 331 | 320 | 345 | 387 | 474 | 502 |
| 3 | 160 | 191 | 282 | 318 | 319 | 322 | 367 | 445 | 492 |
| 4 | 197 | 223 | 311 | 343 | 354 | 345 | 370 | 480 | 465 |
| Average ..... | 184 | 212 | 289 | 332 | 334 | 343 | 375 | 461 | 483 |

Set 2.

| Animal No. | Weight, July 25. | Weight after— | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 28 days. | 66 days. | 79 days. | 92 days. | 116 days. | 141 days. | 168 days. |
| **Control Animals.** | | | | | | | | |
| | grm. | grm. | grm. | grm. | grm. | grm. | grm. | grm. |
| 1 | 155 | 278 | 352 | 337 | 365 | 408 | 512 | 537 |
| 2 | 160 | 250 | 343 | 359 | 367 | 448 | 525 | 555 |
| 3 | 260 | 231 | 298 | 272 | 290 | 334 | 407 | 445 |
| 4 | 133 | 212 | 286 | 285 | 300 | 378 | 450 | 417 |
| 5 | 155 | 258 | 355 | 368 | 370 | 450 | 534 | 574 |
| 6 | 126 | 221 | 276 | 287 | 312 | 353 | 377 | 357 |
| 7 | 220 | 321 | 395 | 393 | 394 | 452 | 522 | 573 |
| 8 | 186 | 256 | 336 | 330 | 340 | 419 | 478 | 475 |
| Average ..... | 174 | 253 | 330 | 329 | 342 | 405 | 475 | 490 |
| **Operated Animals.** | | | | | | | | |
| 1 | 181 | 257 | 318 | 323 | 327 | 382 | 428 | 490 |
| 2 | 190 | 286 | 346 | 363 | 382 | 437 | 480 | 552 |
| 3 | 136 | 235 | 291 | 302 | 327 | 358 | 407 | 390 |
| 4 | 175 | 268 | 340 | 337 | 340 | 400 | 450 | 487 |
| 5 | 156 | 270 | 377 | 383 | 410 | 430 | 517 | 570 |
| 6 | 173 | 250 | 268 | 273 | 297 | 327 | 383 | 395 |
| 7 | 170 | 277 | 386 | 380 | 410 | 435 | 512 | 567 |
| 8 | 212 | 275 | 336 | 346 | 287 | 379 | 423 | 470 |
| Average ..... | 174 | 264 | 333 | 338 | 347 | 393 | 450 | 490 |

Experiment 8 (fig. 3): *Effect of the Simultaneous Removal of the Testes and Thymus on the Growth of the Animal.*—The animals in this experiment were treated as in the previous experiment, the operations extending from July 30 to August 5. The first collective weighing took place on August 22. There were 5 operated and 5 control animals. The results obtained in this experiment confirm the findings in Experiment 7.

| Animal No. | Weight, Aug. 22. | Weight after— 38 days. | 51 days. | 64 days. | 88 days. | 113 days. | 140 days. | 152 days. |
|---|---|---|---|---|---|---|---|---|
| **Control Animals.** | | | | | | | | |
| | grm. | grm. | grm. | grm. | grm. | grm. | grm. | grm. |
| 1 | 203 | 309 | 340 | 397 | 495 | 498 | 577 | 590 |
| 2 | 285 | 374 | 396 | 422 | 484 | 572 | 537 | 547 |
| 3 | 278 | 320 | 335 | 355 | 452 | 520 | 567 | 548 |
| 4 | 157 | 146 | 180 | 232 | 319 | 409 | 465 | 465 |
| 5 | 183 | 330 | 360 | 380 | 462 | 537 | 585 | 575 |
| Average ..... | 221 | 296 | 322 | 357 | 442 | 507 | 546 | 545 |
| **Operated Animals.** | | | | | | | | |
| 1 | 243 | 382 | 435 | 407 | 469 | 537 | 607 | 622 |
| 2 | 135 | 176 | 177 | 235 | 284 | 354 | 350 | 360 |
| 3 | 230 | 373 | 405 | 435 | 487 | 552 | 607 | 600 |
| 4 | 152 | 286 | 320 | 365 | 402 | 485 | 520 | 565 |
| 5 | 217 | 360 | 402 | 387 | 482 | 525 | 606 | 615 |
| Average ..... | 195 | 315 | 347 | 366 | 425 | 491 | 538 | 552 |

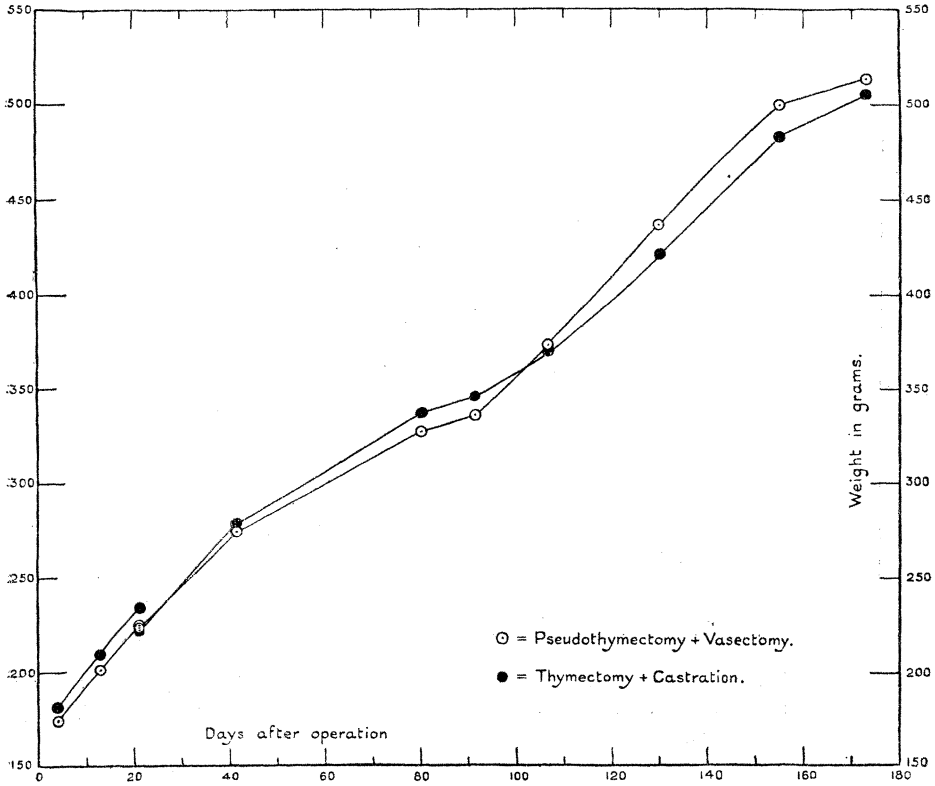


FIG. 3.—Effect of Thymectomy and Castration on the Growth of Guinea-pigs.

(The curves are produced from Experiments 7 and 8, the averages of Experiment 8 and of the second set in Experiment 7 being interpolated to give the approximate average weights on the desired intervals after operation. The separate portion at the beginning of the curve is due to the fact that the weighings of certain animals only commenced 20 days after operation.)

Experiment 9 (fig. 4): *Effect of Semi-Castration on the Weight of the Thymus.*—In this set 7 animals were semi-castrated. The results, in so far as these related to the thymus weights, were too variable to admit of any importance being attached to them.

| Animal No. | Weight, August 13. | Weight after 51 days. | Weight of remaining testis. | Weight of thymus. |
|---|---|---|---|---|
| | grm. | grm. | grm. | grm. |
| 1 | 117 | 310 | 0·652 | 0·355 |
| 2 | 134 | 358 | 1·214 | 0·480 |
| 3 | 136 | 350 | 1·048 | 0·380 |
| 4 | 117 | 363 | 1·206 | 0·550 |
| 5 | 154 | 362 | 1·312 | 0·385 |
| 6 | 123 | 368 | 1·100 | 0·546 |
| 7 | 148 | 356 | 1·400 | 0·252 |
| Average..... | 133 | 352 | — | 0·421 |

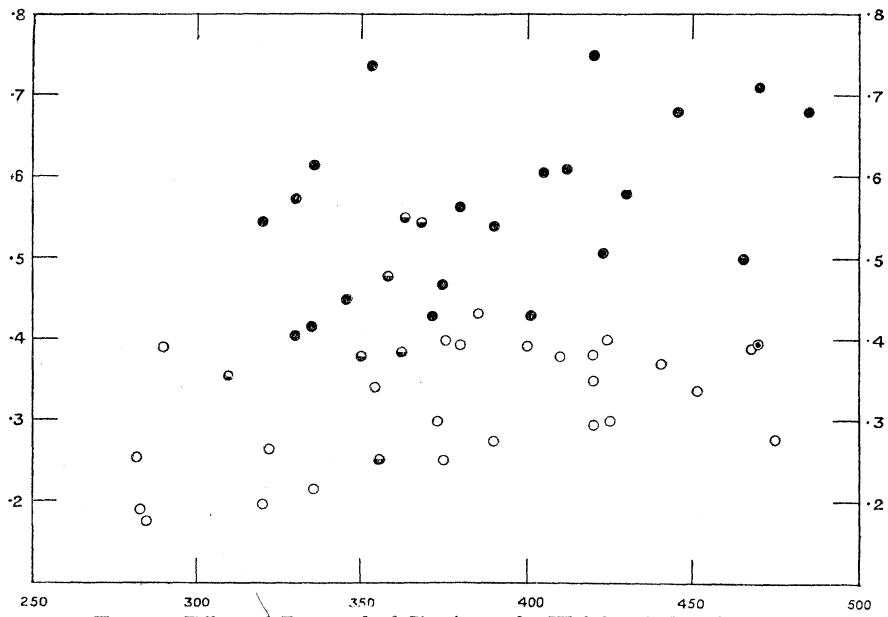


Fig. 4.—Effect of Removal of Testis on the Weight of the Thymus.

(Blacked circles, castrated animals; semi-blacked circles, semi-castrated animals; clear circles, control animals. Vertical, weight of thymus in grammes; horizontal, body weight in grammes.)

Experiment 10: *Effects of the Removal of the Ovaries on the Weight of the Thymus.*—Five females were castrated August 11–14, and compared with 6 controls. The experiment extended from August 11 to October 9. Reference to the data given will show that castration in the female, as in the male, leads to an arrested atrophy and continued growth of the thymus gland.

| Animal No. | Weight, August 11. | Weight after 59 days. | Weight of thymus. |
|---|---|---|---|
| | Control Animals. | | |
| | grm. | grm. | grm. |
| 1 | 182 | 334 | 0·305 |
| 2 | 170 | 246 | 0·190 |
| 3 | 160 | 326 | 0·363 |
| 4 | 177 | 320 | 0·280 |
| 5 | 158 | 365 | 0·400 |
| 6 | 181 | 350 | 0·320 |
| Average ..... | 171 | 323 | 0·309 |
| | Operated Animals. | | |
| 1 | 162 | 424 | 0·805 |
| 2 | 160 | 326 | 0·405 |
| 3 | 153 | 406 | 0·720 |
| 4 | 170 | 415 | 0·780 |
| 5 | 145 | 341 | 0·590 |
| Average ..... | 158 | 382 | 0·660 |

Experiment 11 (fig. 5): *Effect of Removal of the Thymus on the Weight of the Testes and on the Growth of the Animal.*—Nine animals thymectomised October 21, 9 controls. The experiment extended from October 21 to November 18, by which time 6 operated animals and 7 normal animals were over 300 grm. in weight. The evidence here confirms the findings of Experiments 2, 5 and 6.

| Animal No. | Weight, Oct. 21. | After 28 days. | Test. and epid. | Thymus. |
|---|---|---|---|---|
| | | Control Animals. | | |
| | grm. | grm. | grm. | grm. |
| 1 | 277 | 332 | 1·650 | 0·330 |
| 2 | 253 | 308 | 0·820 | 0·330 |
| 3 | 217 | 233 | 0·340 | 0·120 |
| 4 | 298 | 335 | 1·065 | 0·290 |
| 5 | 205 | 282 | 0·520 | 0·375 |
| 6 | 260 | 315 | 0·770 | 0·340 |
| 7 | 348 | 392 | 2·556 | 0·290 |
| 8 | 272 | 370 | 1·695 | 0·250 |
| 9 | 312 | 350 | 2·230 | 0·235 |
| Average ..... | 271 | 324 | 1·294 | 0·284 |
| | | Operated Animals. | | |
| | grm. | grm. | grm. | |
| 1 | 270 | 342 | 1·010 | |
| 2 | 277 | 350 | 1·174 | |
| 3 | 227 | 303 | 1·535 | |
| 4 | 287 | 281 | 0·544 | |
| 5 | 207 | 278 | 0·470 | |
| 6 | 320 | 355 | 1·186 | |
| 7 | 370 | 425 | 2·504 | |
| 8 | 276 | 362 | 1·610 | |
| 9 | 240 | 298 | 1·125 | |
| Average ..... | 275 | 332 | 1·239 | |

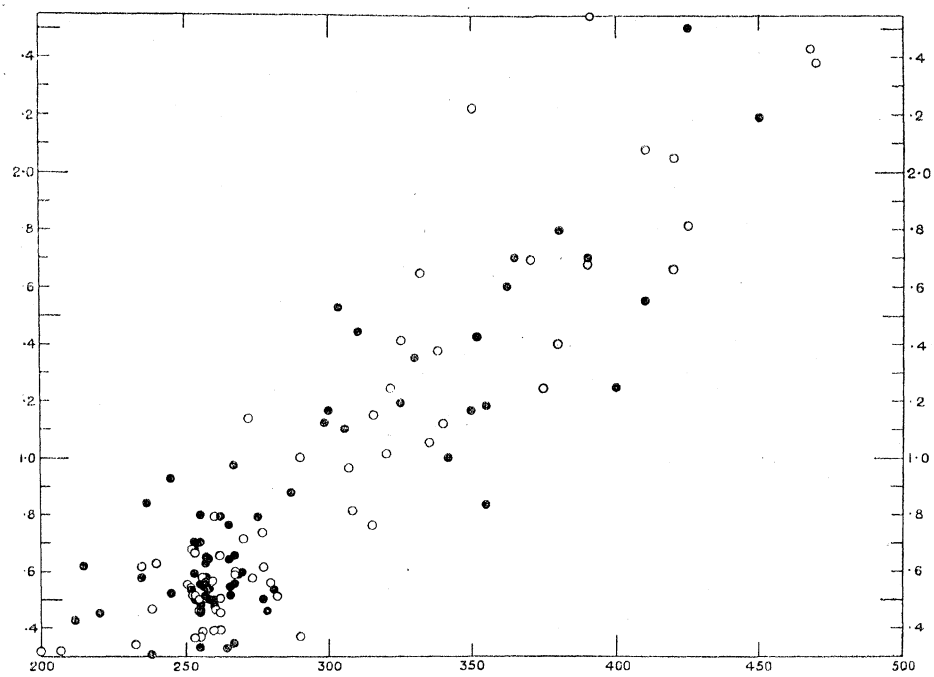


Fig. 5.—Effect of Removal of Thymus on the Weight of the Testis.
(Clear circles, control animals ; black circles, operated animals. Vertical, weight of testes and epididymes in grammes ; horizontal, weight of animal in grammes.)

Experiments 12 to 17 : *Effect of the Removal of the Thymus on the Weight of the Testes.*—In these experiments, the chief intention was to investigate the effect of thymectomy on the weight of the testes. In order to cut out the enormous variation in the weight of the testes obtained as the animal approaches puberty all animals were killed when they attained the weight of about 260 grm.

Reference to fig. 5, on which the results obtained from this and other experiments are plotted, shows that thymectomy does not lead to a compensating acceleration in the growth of the testes.

| Experiment. | Animals used. | | Initial average weight in grammes. | |
|---|---|---|---|---|
| | Normals. | Operated. | Normals. | Operated. |
| 12 | 8 | 6 | 188 | 166 |
| 13 | — | 5 | — | 164 |
| 14 | 7 | 5 | 185 | 191 |
| 15 | 6 | 5 | 139 | 145 |
| 16 | 9 | 7 | 166 | 187 |
| 17 | — | 4 | — | 174 |

Experiment 12.

| Initial weight. | Final weight. | Weight of testes. | Initial weight. | Final weight. | Weight of testes. |
|---|---|---|---|---|---|
| Control Animals. | | | Operated Animals. | | |
| grm. | grm. | grm. | grm. | grm. | grm. |
| 187 | 277 | 0·620 | 153 | 257 | 0·550 |
| 222 | 270 | 0·720 | 207 | 268 | 0·590 |
| 170 | 254 | 0·465 | 174 | 275 | 0·795 |
| 175 | 254 | 0·514 | 138 | 266 | 0·550 |
| 187 | 255 | 0·456 | 162 | 255 | 0·460 |
| 202 | 267 | 0·603 | 162 | 257 | 0·655 |
| 200 | 267 | 0·590 | | | |
| 163 | 260 | 0·795 | | | |
| Average..... 188 | 263 | 0·598 | 166 | 263 | 0·600 |

Experiment 13.

| Initial weight. | Final weight. | Weight of testes. |
|---|---|---|
| Operated Animals. | | |
| grm. | grm. | grm. |
| 165 | 260 | 0·480 |
| 170 | 277 | 0·515 |
| 135 | 266 | 0·490 |
| 160 | 269 | 0·600 |
| 190 | 257 | 0·580 |
| Average ..... 164 | 266 | 0·533 |

Experiment 14.

| Initial weight. | Final weight. | Weight of testes. | Initial weight. | Final weight. | Weight of testes. |
|---|---|---|---|---|---|
| Control Animals. | | | Operated Animals. | | |
| grm. | grm. | grm. | grm. | grm. | grm. |
| 137 | 261 | 0·470 | 210 | 258 | 0·540 |
| 177 | 255 | 0·370 | 227 | 267 | 0·568 |
| 240 | 252 | 0·520 | 182 | 258 | 0·512 |
| 177 | 256 | 0·385 | 172 | 255 | 0·710 |
| 197 | 253 | 0·370 | 165 | 267 | 0·663 |
| — | 252 | 0·545 | | | |
| — | 258 | 0·572 | | | |
| Average ..... — | 255 | 0·462 | 191 | 261 | 0·598 |

Experiment 15.

| Initial weight. | Final weight. | Weight of testes. | Initial weight. | Final weight. | Weight of testes. |
|---|---|---|---|---|---|
| Control Animals. | | | Operated Animals. | | |
| grm. | grm. | grm. | grm. | grm. | grm. |
| 165 | 262 | 0·460 | 155 | 253 | 0·710 |
| 108 | 262 | 0·660 | 107 | 253 | 0·590 |
| 107 | 253 | 0·670 | 210 | 255 | 0·560 |
| 130 | 277 | 0·505 | 132 | 257 | 0·520 |
| 165 | 251 | 0·564 | 120 | 252 | 0·530 |
| 160 | 262 | 0·390 | | | |
| Average ..... 139 | 261 | 0·541 | 145 | 254 | 0·582 |

Experiment 16.

| Initial weight. | Final weight. | Weight of testes. | Initial weight. | Final weight. | Weight of testes. |
|---|---|---|---|---|---|
| Control Animals. | | | Operated Animals. | | |
| grm. | grm. | grm. | grm. | grm. | grm. |
| 128 | 258 | 0·390 | 132 | 267 | 0·350 |
| 150 | 253 | 0·520 | 209 | 267 | 0·976 |
| 129 | 254 | 0·510 | 207 | 264 | 0·330 |
| 128 | 255 | 0·710 | 215 | 255 | 0·330 |
| 160 | 262 | 0·520 | 167 | 255 | 0·800 |
| 135 | 256 | 0·580 | 202 | 259 | 0·507 |
| 219 | 273 | 0·580 | 183 | 255 | 0·480 |
| 236 | 278 | 0·740 | | | |
| 215 | 279 | 0·570 | | | |
| Average ..... 166 | 263 | 0·569 | 187 | 260 | 0·539 |

Experiment 17.

| Initial weight. | Final weight. | Weight of testes. |
|---|---|---|
| Operated Animals. | | |
| grm. | grm. | grm. |
| 198 | 253 | 0·503 |
| 172 | 262 | 0·790 |
| 152 | 255 | 0·465 |
| — | 253 | 0·680 |
| 174 | 256 | 0·609 |

*Summary of Conclusions.*

From the evidence given in the above set of experiments, where, in investigating growth effects, the authors were careful to compensate for any possible operative effects, are drawn the following conclusions :—

(1) Removal of the thymus in young guinea-pigs does not affect the growth of the animals.

(2) Removal of the testes and epididymes in young guinea-pigs does not affect the growth of the animals before sexual maturity.

(3) Simultaneous removal of the testes and thymus in young guinea-pigs does not affect the growth of the animals before sexual maturity.

(4) Thymectomy is not followed by hypertrophy of the testes.

(5) Castration leads to an arrested atrophy and subsequent hypertrophy of the thymus gland, as found by other investigators.

(6) There is no evidence of the existence of a compensatory mechanism between the testes and the thymus.

The work was carried on at the Field Laboratories, Cambridge. The operations were done by F. H. A. Marshall; the weighings and the chief part of the other work by E. T. Halnan. The expenses were defrayed by a grant made by the Board of Agriculture and Fisheries out of funds placed at their disposal by the Development Commission.

*Note by* G. UDNY YULE.

In view of the disagreement with Prof. Paton's conclusions, Dr. Marshall asked me to investigate the probable errors of some of the comparisons made, with especial reference to the alleged effect of extirpation of the thymus on the growth of the testes.

The problem was not an easy one. A glance at Prof. Paton's figures, or at the corresponding data given by Halnan and Marshall, will show how exceedingly variable are the weights of the testes and how much caution must consequently be used before basing any conclusion on a small difference between the average weights for two groups of some 20 to 30 animals. Considerable differences might be shown even by the averages of groups treated in precisely the same way. Were the animals adult, the "probable error" of the difference between any two observed averages—the amount which it would be as likely as not to exceed owing to mere fluctuations of sampling—might be readily obtained in the ordinary way. But the animals are not adult; the weight of the testes increases very rapidly with the weight of the animal, and the weights of the different individuals themselves vary greatly, so that the two groups of operated and controls are not strictly comparable as a whole.

What I finally decided to do, therefore, was this: To obtain, by known methods, equations expressing as closely as possible the relation between mean weight of the testes and body-weight, for operated and for normal animals, and to see whether the constants in these equations differed more than could be expected owing to the chances of sampling alone. As in Prof. Paton's data the weight of testes did not seem to be a linear function of the body-weight, and it was these data that I first investigated, the logarithm of the testes-weight was substituted for the actual value, and this seemed to give an approximately linear relation, judging from the diagram (fig. 6). The two equations, with the probable errors of the constants which I finally obtained from Prof. Paton's data, including all the 23 normal