# ON THE RELATIVE GROWTH OF THE ORGANS AND PARTS OF THE EMBRYONIC AND YOUNG DOGFISH (MUSTELIS CANIS)

by

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## INTRODUCTION

In general, but little attention has been paid to the relative growth of the various organs in fishes. Some scattering observations are included in the work of Welcker and Brandt ('03). The most complete data are those of Kellicott ('08) on the dogfish. These, however, deal only with the relations from birth onward. A knowledge of the earlier embryonic conditions is very desirable in order to trace more completely the growth process and to give a more extended basis for comparison with higher vertebrates. Therefore the purpose of the present paper is to present and discuss some original observations on the relative growth of the viscera and parts of the embryonic dogfish. Some original data on the postnatal relative growth of the young dogfish are included for comparison with embryonic growth and with postnatal data already in the literature. Also observations on fourteen specimens of Amiurus are included for comparison with the teleost. The relative growth of the dogfish is briefly compared in a general way with the data in the literature on the relative growth of higher vertebrates, especially mammals.

This work was done in the Anatomical Laboratory of the University of Missouri under the direction of Dr. C.M. Jackson, to whom I am deeply indebted for invaluable criticism and suggestions.

General Table of Individual Observations (Mustelis canis)

| No. | sex | net body wt. in grams. | length total | length trunk | head net weight | head rel. weight |
|---|---|---|---|---|---|---|
| 1 | f. | 1498.8000 | 800.0 | 385.0 | 193.0000 | 12.876 |
| 2 | f. | 360.4720 | 472.0 | 215.0 | 43.7920 | 12.148 |
| 3 | m. | 352.4810 | 495.0 | 225.0 | 45.4260 | 12.887 |
| 4 | m. | 344.0810 | 452.0 | 210.0 | 31.2660 | 9.086 |
| 5 | f. | 331.5120 | 488.0 | 218.0 | 47.7460 | 14.402 |
| 6 | m. | 133.4390 | 376.0 | 168.0 | 19.7710 | 14.816 |
| 7 | m. | 131.4440 | 382.0 | 173.0 | 19.4160 | 14.771 |
| 8 | m. | 121.2700 | 315.0 | 145.0 | 16.2230 | 13.377 |
| 9 | m. | 102.2950 | 339.0 | 151.0 | 17.6280 | 17.232 |
| 10 | f. | 92.7900 | 343.0 | 151.0 | 15.3930 | 16.589 |
| 11 | m. | 82.1100 | 320.0 | 143.0 | 13.8810 | 16.905 |
| 12 | m. | 72.3500 | 321.0 | 143.0 | 11.6407 | 16.088 |
| 13 | f. | 65.6200 | 306.0 | 141.0 | 11.3640 | 17.317 |
| 14 | f. | 59.1600 | 280.0 | 125.0 | 9.5780 | 16.190 |
| 15 | m. | 53.2430 | 283.0 | 124.0 | 8.9410 | 16.791 |
| 16 | m. | 48.8350 | 279.0 | 130.0 | 7.7050 | 15.777 |
| 17 | f. | 47.5440 | 273.0 | 125.0 | 9.7930 | 20.597 |
| 18 | m. | 42.0750 | 253.0 | 115.0 | 8.1380 | 19.341 |
| 19 | f. | 5.2600 | 113.0 | 54.0 | .7090 | 13.479 |
| 20 | f. | 5.0330 | 113.0 | 55.0 | 1.0712 | 21.283 |
| 21 | f. | 4.9824 | 111.5 | 53.0 | 1.1386 | 22.852 |
| 22 | f. | 4.8142 | 104.0 | 49.0 | 1.1781 | 24.471 |
| 23 | m. | 4.7718 | 112.0 | 52.5 | 1.1126 | 23.315 |
| 24 | m. | 3.8710 | 106.0 | 49.5 | .9622 | 24.856 |
| 25 | f. | 3.8338 | 102.0 | 48.5 | .8753 | 22.831 |
| 26 | m. | 3.8260 | 100.0 | 46.0 | .7792 | 20.365 |
| 27 | f. | 3.7967 | 98.5 | 47.0 | .9654 | 25.427 |
| 28 | f. | 3.6524 | 101.0 | 48.0 | .9158 | 25.073 |
| 29 | f. | 3.5160 | 93.0 | 46.0 | .6952 | 19.722 |
| 30 | f. | 2.6060 | 85.0 | 43.0 | .5072 | 19.462 |
| 31 | m. | 1.7440 | 70.0 | 36.0 | .3012 | 17.270 |
| 32 | m. | 1.1390 | 65.0 | 32.0 | .3211 | 28.216 |
| 33 | m. | .8264 | 59.5 | 28.0 | .2378 | 28.775 |
| 34 | m. | .7460 | 54.0 | 26.0 | .1892 | 25.361 |
| 35 | m. | .5253 | 49.0 | 24.0 | .1656 | 31.524 |
| 36 | f. | .4120 | 43.0 | 21.0 | .1262 | 30.631 |
| 37 | m. | .3697 | 45.0 | 20.1 | .1264 | 34.298 |
| 38 | m. | .3344 | 45.0 | 20.0 | .0987 | 28.910 |
| 39 | ? | .3130 | 40.0 | 21.0 | .0952 | 30.415 |
| 40 | ? | .2510 | 37.0 | 19.0 | .0722 | 28.764 |
| 41 | ? | .1867 | 35.5 | 18.0 | .0591 | 31.655 |
| 42 | ? | .1040 | 27.0 | 16.0 | .0391 | 37.596 |
| 43 | ? | .0916 | 26.0 | 15.0 | .0371 | 40.502 |
| 44 | ? | .0608 | 25.0 | 14.0 | .0234 | 38.486 |
| 45 | ? | .0509 | 24.0 | 12.5 | .0107 | 21.021 |
| 46 | ? | .0445 | 25.0 | 13.0 | .0158 | 35.505 |
| 47 | ? | .0084 | 16.0 | ---- | .0018 | 21.428 |

General Table of Individual Observations, continued. (Mustelis canis)

| No. | brain | | spinal cord | | eyeballs | |
|---|---|---|---|---|---|---|
| | net wt. | rel. wt. | net wt. | rel. wt. | net wt. | rel wt. |
| 1 | 6.2980 | .420 | 2.4970 | .166 | 9.5410 | .636 |
| 2 | 2.3270 | .645 | .7860 | .218 | 3.3310 | .924 |
| 3 | 2.0590 | .584 | .8120 | .230 | 4.0030 | 1.135 |
| 4 | 2.0120 | .584 | .7660 | .222 | 3.0030 | .872 |
| 5 | 3.0990 | .934 | 1.2600 | .380 | 5.2600 | 1.586 |
| 6 | 1.6660 | 1.248 | .5050 | .378 | 2.4320 | 1.822 |
| 7 | 1.6760 | 1.275 | .5770 | .438 | 2.4860 | 1.891 |
| 8 | 1.4570 | 1.201 | .4680 | .385 | 2.1530 | 1.775 |
| 9 | 2.3000 | 2.248 | .3330 | .325 | 2.1300 | 2.082 |
| 10 | 1.2280 | 1.323 | .3480 | .375 | 1.2360 | 1.332 |
| 11 | 1.0730 | 1.184 | .2840 | .345 | 1.7810 | 2.169 |
| 12 | .9457 | 1.311 | .3157 | .436 | 1.0297 | 1.423 |
| 13 | .9300 | 1.417 | .2390 | .364 | 1.5480 | 2.359 |
| 14 | .8930 | 1.509 | .2080 | .351 | .9550 | 1.614 |
| 15 | .7460 | 1.401 | .2130 | .400 | 1.2430 | 2.334 |
| 16 | .9880 | 2.023 | .2790 | .571 | .8740 | 1.789 |
| 17 | .8740 | 1.838 | .1710 | .359 | 1.3160 | 2.765 |
| 18 | .7860 | 1.868 | .2090 | .496 | 1.1340 | 2.695 |
| 19 | .0660 | 1.254 | ---- | --- | .1160 | 2.205 |
| 20 | .1092 | 2.169 | .0182 | .361 | .1732 | 3.441 |
| 21 | .1345 | 2.699 | .0141 | .282 | .2428 | 4.873 |
| 22 | .0932 | 1.935 | .0174 | .361 | .1858 | 3.859 |
| 23 | .1318 | 2.762 | .0170 | .356 | .2528 | 5.297 |
| 24 | .1231 | 3.180 | .0100 | .258 | .1901 | 4.910 |
| 25 | .1166 | 3.041 | .0084 | .219 | .1996 | 5.206 |
| 26 | .0742 | 1.939 | .0062 | .162 | .1522 | 3.978 |
| 27 | .1142 | 3.007 | .0089 | .234 | .1889 | 4.975 |
| 28 | .1014 | 2.776 | .0107 | .292 | .1847 | 5.056 |
| 29 | .0622 | 1.769 | ---- | --- | .0942 | 2.679 |
| 30 | .0662 | 2.540 | .0062 | .237 | .0752 | 2.885 |
| 31 | .0392 | 2.247 | .0112 | .642 | .0592 | 3.394 |
| 32 | .0574 | 5.043 | .0037 | .325 | .0491 | 4.314 |
| 33 | .0501 | 6.062 | .0049 | .592 | .0451 | 5.457 |
| 34 | .0452 | 6.058 | ---- | --- | .0382 | 5.120 |
| 35 | .0401 | 7.633 | .0034 | .647 | .0273 | 5.197 |
| 36 | .0362 | 8.786 | .0032 | .776 | .0192 | 4.660 |
| 37 | .0284 | 7.681 | .0028 | .757 | .0196 | 5.301 |
| 38 | .0268 | 7.850 | .0037 | 1.083 | .0171 | 5.008 |
| 39 | .0172 | 5.495 | .00[illegible] | .702 | .0182 | 5.814 |
| 40 | .0082 | 3.266 | ---- | --- | .0182 | 7.250 |
| 41 | .0195 | 10.444 | .0033 | 1.767 | .0075 | 4.017 |
| 42 | .0111 | 10.673 | ---- | --- | .0059 | 5.673 |
| 43 | .0071 | 7.751 | ---- | --- | .0068 | 7.423 |
| 44 | .0092 | 15.131 | ---- | --- | .0057 | 9.375 |
| 45 | .0042 | 8.251 | ---- | --- | --- | ----- |
| 46 | .0050 | 11.235 | ---- | --- | .0015 | 3.370 |
| 47 | .0013 | 15.476 | ---- | --- | .0002 | 2.380 |

General Table of Individual Observations, continued. (Mustelis canis)

| No. | skin | | skeleton and lgt. | | heart | |
|---|---|---|---|---|---|---|
| | net wt. | rel. wt. | net wt. | rel. wt. | net wt. | rel. wt. |
| 1 | 109.0070 | 7.272 | 136.3000 | 9.093 | 3.0030 | .200 |
| 2 | 31.0410 | 8.611 | 32.4460 | 9.001 | .8230 | .228 |
| 3 | 30.2750 | 8.589 | 31.1860 | 8.819 | .7000 | .198 |
| 4 | 22.4030 | 6.510 | 24.4110 | 7.094 | .5030 | .146 |
| 5 | 36.2110 | 10.923 | 40.2310 | 12.135 | .6590 | .198 |
| 6 | 11.9460 | 8.952 | 14.0000 | 10.491 | .2730 | .204 |
| 7 | 15.0540 | 11.452 | 14.1060 | 10.731 | .2360 | .179 |
| 8 | 8.9850 | 7.409 | 8.3150 | 6.848 | .2330 | .192 |
| 9 | 12.5710 | 12.288 | 9.0590 | 8.855 | .1760 | .172 |
| 10 | 13.4840 | 14.531 | 7.9310 | 8.547 | .1940 | .209 |
| 11 | 7.2460 | 8.824 | 6.8490 | 8.341 | .1650 | .200 |
| 12 | 8.5527 | 11.821 | 7.6357 | 10.553 | .0777 | .107 |
| 13 | 8.1820 | 12.468 | 5.9060 | 9.000 | .1240 | .188 |
| 14 | 7.3750 | 12.466 | ------ | ----- | .0730 | .123 |
| 15 | 5.4160 | 10.172 | 4.0280 | 7.565 | .0580 | .108 |
| 16 | 6.4430 | 13.193 | 2.9720 | 6.085 | .0850 | .174 |
| 17 | 6.2610 | 13.166 | 3.4980 | 7.357 | .0910 | .191 |
| 18 | 3.9910 | 9.485 | 3.4750 | 8.259 | .0760 | .180 |
| 19 | .3680 | 6.996 | .2160 | 4.102 | ---- | --- |
| 20 | .4302 | 8.547 | .3430 | 6.815 | .0192 | .381 |
| 21 | .3080 | 6.181 | ---- | ----- | .0071 | .142 |
| 22 | .3635 | 7.550 | ---- | ----- | .0123 | .255 |
| 23 | .2890 | 6.056 | ---- | ----- | .0102 | .213 |
| 24 | .3224 | 8.328 | ---- | ----- | .0072 | .185 |
| 25 | .2781 | 7.253 | ---- | ----- | .0101 | .263 |
| 26 | .2892 | 7.558 | .1722 | 4.500 | .0062 | .162 |
| 27 | .2741 | 7.219 | ---- | ----- | .0086 | .226 |
| 28 | .2184 | 5.979 | ---- | ----- | .0119 | .325 |
| 29 | .2712 | 7.713 | ---- | ----- | .0152 | .432 |
| 30 | .2272 | 8.718 | .2032 | 7.797 | .0132 | .506 |
| 31 | .0802 | 4.598 | ---- | ----- | .0122 | .699 |
| 32 | .0684 | 6.010 | ---- | ----- | .0029 | .254 |
| 33 | .0585 | 7.078 | ---- | ----- | .0024 | .290 |
| 34 | .0372 | 4.986 | ---- | ----- | .0032 | .428 |
| 35 | .0295 | 5.615 | ---- | ----- | .0013 | .247 |
| 36 | .0232 | 5.631 | ---- | ----- | ---- | --- |
| 37 | .0246 | 6.654 | ---- | ------ | .0007 | .188 |
| 38 | .0214 | 6.268 | ---- | ----- | .0010 | .292 |
| 39 | ---- | ----- | ---- | ----- | .0032 | 1.022 |
| 40 | ---- | ----- | ---- | ----- | .0022 | .876 |
| 41 | ---- | ----- | ---- | ----- | ---- | --- |
| 42 | ---- | ----- | ---- | ----- | .0003 | .288 |
| 43 | ---- | ----- | ---- | ----- | ---- | --- |
| 44 | ---- | ----- | ---- | ----- | .0005 | .822 |
| 45 | ---- | ----- | ---- | ----- | ---- | --- |
| 46 | ---- | ----- | ---- | ----- | .0019 | 4.269 |
| 47 | ---- | ----- | ---- | ----- | .0002 | 2.380 |

General Table of Individual Observations, continued. (Mustelis canis)

| No. | musculature | | pancreas | | liver | |
|---|---|---|---|---|---|---|
| | net wt. | rel. wt. | net wt. | rel. wt. | net wt. | rel. wt. |
| 1 | 939.6000 | 62.960 | ---- | --- | 88.1000 | 5.878 |
| 2 | 198.5540 | 55.081 | .5920 | .164 | 31.9230 | 8.855 |
| 3 | 213.8140 | 60.659 | .4320 | .122 | 21.2610 | 6.031 |
| 4 | 223.5890 | 64.981 | .4440 | .129 | 29.8560 | 8.676 |
| 5 | 171.2690 | 51.662 | .4810 | .145 | 12.9640 | 3.910 |
| 6 | 77.1460 | 57.813 | .1610 | .120 | 6.2160 | 4.658 |
| 7 | 46.9900 | 35.749 | .1910 | .145 | 4.2410 | 3.226 |
| 8 | 33.5050 | 27.628 | .1030 | .084 | 6.4130 | 5.287 |
| 9 | 49.3270 | 48.220 | .0650 | .063 | 5.5060 | 5.382 |
| 10 | 49.8550 | 53.728 | .0580 | .062 | 5.4310 | 5.853 |
| 11 | 40.0870 | 48.821 | .0630 | .076 | 5.2390 | 6.380 |
| 12 | 26.4357 | 36.538 | .0227 | .031 | 3.2497 | 4.491 |
| 13 | 31.9050 | 48.620 | .0410 | .062 | 3.9620 | 6.037 |
| 14 | ------- | ------ | .0310 | .052 | 3.1150 | 5.265 |
| 15 | 20.4830 | 38.470 | ---- | --- | 1.6660 | 3.129 |
| 16 | 28.3600 | 57.868 | ---- | --- | 2.8950 | 5.928 |
| 17 | 22.1680 | 46.415 | .0380 | .079 | 2.5130 | 5.285 |
| 18 | ------- | ------ | .0320 | .076 | 1.8130 | 4.308 |
| 19 | 1.3810 | 26.254 | ---- | --- | .2110 | 4.011 |
| 20 | 1.8300 | 36.360 | .0027 | .053 | .2962 | 5.885 |
| 21 | 2.0601 | 41.347# | ---- | --- | .2238 | 4.491 |
| 22 | 2.4445 | 50.776# | .0026 | .054 | .2371 | 4.925 |
| 23 | 2.2113 | 46.341# | .0041 | .085 | .1832 | 3.839 |
| 24 | 1.6363 | 42.270# | .0034 | .087 | .1605 | 4.146 |
| 25 | 1.7740 | 46.272# | .0031 | .080 | .1505 | 3.925 |
| 26 | 1.8900 | 49.390 | .0013 | .033 | .2032 | 5.308 |
| 27 | 1.3463 | 35.459# | .0031 | .081 | .1629 | 4.290 |
| 28 | 1.9913 | 54.520# | .0028 | .076 | .1806 | 4.944 |
| 29 | .7980 | 22.696 | .0021 | .059 | .1742 | 4.954 |
| 30 | .9830 | 37.720 | .0009 | .034 | .1285 | 4.930 |
| 31 | .7482 | 42.901# | .0007 | .040 | .1062 | 6.089 |
| 32 | .4717 | 41.362# | .0008. | .070 | .0575 | 5.052 |
| 33 | .3624 | 43.852# | .0012 | .145 | .0536 | 6.485 |
| 34 | .2612 | 35.013# | .0002 | .026 | .0342 | 4.584 |
| 35 | .2078 | 39.558# | .0002 | .038 | .0270 | 5.139 |
| 36 | .1912 | 46.407# | .0001 | .024 | .0252 | 6.116 |
| 37 | .1570 | 42.466# | .0003 | .080 | .0186 | 5.031 |
| 38 | .1524 | 44.639# | .0004 | .117 | .0138 | 4.042 |
| 39 | .1452 | 46.389# | .0002 | .063 | .0242 | 7.731 |
| 40 | .1182 | 47.091# | .0001 | .039 | .0160 | 6.374 |
| 41 | .0907 | 48.580# | .0002 | .107 | .0103 | 5.516 |
| 42 | ---- | ------ | ---- | --- | .0025 | 2.403 |
| 43 | ---- | ------ | ---- | --- | .0018 | 1.965 |
| 44 | ---- | ------ | ---- | --- | .0015 | 2.467 |
| 45 | ---- | ------ | ---- | --- | ---- | ----- |
| 46 | ---- | ------ | ---- | --- | .0013 | 2.921 |
| 47 | ---- | ------ | ---- | --- | ---- | ----- |

# musculature plus skeleton

General Table of Individual Observations, continued. (Mustelis canis)

| No. | spleen | | empty stomach-intestines | | rectal gland | |
|---|---|---|---|---|---|---|
| | net wt. | rel. wt. | net wt. | rel. wt. | net wt. | rel. wt. |
| 1 | 2.7780 | .185 | 43.8000 | 2.255 | .3410 | .022 |
| 2 | 1.4120 | .391 | 17.1980 | 4.770 | .1620 | .044 |
| 3 | 1.2490 | .360 | 13.6160 | 3.862 | .1080 | .030 |
| 4 | 1.3850 | .402 | 16.4670 | 4.785 | .1530 | .044 |
| 5 | 1.1910 | .359 | 18.1880 | 5.486 | ---- | --- |
| 6 | .4780 | .358 | 5.7010 | 4.272 | .0730 | .054 |
| 7 | .3860 | .293 | 5.8460 | 4.447 | .0460 | .034 |
| 8 | .1730 | .142 | 3.9850 | 3.285 | .0450 | .037 |
| 9 | .1070 | .104 | 2.9900 | 2.922 | .0360 | .035 |
| 10 | .1030 | .111 | 2.6210 | 2.824 | .0430 | .046 |
| 11 | .1160 | .141 | 2.1900 | 2.667 | ---- | --- |
| 12 | .0817 | .112 | 2.0340 | 2.811 | .0097 | .013 |
| 13 | .0790 | .120 | .8770 | 1.336 | .0270 | .041 |
| 14 | .0530 | .089 | 1.6350 | 2.763 | .0140 | .023 |
| 15 | .0370 | .069 | 1.2970 | 2.436 | .0300 | .056 |
| 16 | .0530 | .108 | 2.0730 | 4.244 | .0250 | .051 |
| 17 | .0560 | .117 | 1.7490 | 3.657 | .0230 | .048 |
| 18 | .0340 | .080 | 1.4680 | 3.489 | .0150 | .035 |
| 19 | ---- | --- | .1460 | 2.775 | .0020 | .038 |
| 20 | .0053 | .105 | .0912 | 1.812 | .0062 | .123 |
| 21 | .0018 | .036 | .0828 | 1.661 | .0050 | .100 |
| 22 | .0017 | .035 | .1734 | 3.601 | .0050 | .103 |
| 23 | .0024 | .050 | .2148 | 4.501 | .0052 | .108 |
| 24 | .0010 | .025 | .1101 | 2.585 | .0040 | .103 |
| 25 | .0011 | .028 | .1519 | 3.962 | .0051 | .133 |
| 26 | .0010 | .026 | .0832 | 2.174 | .0012 | .031 |
| 27 | .0012 | .031 | .0888 | 2.338 | .0054 | .142 |
| 28 | .0010 | .027 | .0861 | 2.357 | .0052 | .142 |
| 29 | .0010 | .028 | .0652 | 1.854 | .0020 | .056 |
| 30 | .0020 | .076 | .0562 | 2.156 | .0012 | .045 |
| 31 | .0010 | .057 | .0412 | 2.362 | .0007 | .040 |
| 32 | .0008 | .070 | .0275 | 2.416 | .0015 | .131 |
| 33 | .0004 | .048 | .0153 | 1.851 | .0011 | .133 |
| 34 | .0006 | .080 | .0162 | 2.171 | .0007 | .093 |
| 35 | .0002 | .038 | .0088 | 1.675 | .0008 | .152 |
| 36 | .0002 | .048 | .0062 | 1.504 | .0002 | .048 |
| 37 | .0002 | .054 | .0082 | 2.217 | .0002 | .054 |
| 38 | .0002 | .058 | .0066 | 1.933 | .0001 | .029 |
| 39 | .0002 | .063 | .0062 | 1.980 | .0007 | .223 |
| 40 | .0001 | .039 | .0052 | 2.071 | .0006 | .239 |
| 41 | .0001 | .053 | ---- | ----- | ---- | --- |
| 42 | ---- | --- | .0039 | 3.750 | ---- | --- |
| 43 | ---- | --- | .0025 | 2.729 | ---- | --- |
| 44 | ---- | --- | .0014 | 2.302 | .0001 | .164 |
| 45 | ---- | --- | ---- | ----- | ---- | --- |
| 46 | ---- | --- | ---- | ----- | ---- | --- |
| 47 | ---- | --- | ---- | ----- | ---- | --- |

General Table of Individual Observations, continued. (Mustelis canis)

| No. | mesonephroi | | gonads | |
|---|---|---|---|---|
| | net wt. | rel. wt. | net wt. | rel. wt. |
| 1 | 5.6610 | .377 | 4.2280 | .282 |
| 2 | 2.9010 | .804 | 3.0960 | .858 |
| 3 | 2.5560 | .725 | 2.6210 | .743 |
| 4 | 2.5560 | .742 | 2.0460 | .594 |
| 5 | 2.7020 | .815 | 2.5590 | .771 |
| 6 | 1.1880 | .890 | 1.3890 | 1.040 |
| 7 | 1.0940 | .832 | .6960 | .529 |
| 8 | .9830 | .802 | .5030 | .414 |
| 9 | .9960 | .973 | .5240 | .512 |
| 10 | .8880 | .956 | .2940 | .316 |
| 11 | .7140 | .869 | .2340 | .284 |
| 12 | .5597 | .773 | .3627 | .501 |
| 13 | .9810 | 1.494 | .2740 | .417 |
| 14 | .5930 | 1.002 | .1970 | .332 |
| 15 | .4400 | .886 | .1280 | .240 |
| 16 | .6930 | 1.419 | .2240 | .458 |
| 17 | .7730 | 1.604 | .2010 | .422 |
| 18 | .4470 | 1.062 | .1510 | .358 |
| 19 | .1570 | 2.965 | .0010 | .019 |
| 20 | .1672 | 3.322 | .0032 | .063 |
| 21 | .2432 | 4.881 | .0046 | .092 |
| 22 | .2003 | 4.160 | .0026 | .054 |
| 23 | .1814 | 3.801 | .0024 | .050 |
| 24 | .1623 | 4.192 | .0031 | .080 |
| 25 | .1364 | 3.557 | .0020 | .052 |
| 26 | .1192 | 3.115 | .0020 | .052 |
| 27 | .1420 | 3.740 | .0016 | .042 |
| 28 | .1353 | 3.704 | .0022 | .060 |
| 29 | .0952 | 2.707 | .0022 | .062 |
| 30 | .0912 | 3.499 | .0017 | .065 |
| 31 | .0642 | 3.681 | .0012 | .068 |
| 32 | .0546 | 4.797 | .0004 | .035 |
| 33 | .0379 | 4.586 | .0007 | .084 |
| 34 | .0142 | 1.903 | .0002 | .026 |
| 35 | .0131 | 2.493 | .0004 | .076 |
| 36 | .0092 | 2.233 | .0002 | .048 |
| 37 | .0115 | 3.110 | .0002 | .054 |
| 38 | .0049 | 1.435 | .0002 | .058 |
| 39 | .0102 | 3.258 | .0004 | .127 |
| 40 | .0042 | 1.673 | .0004 | .159 |
| 41 | .0036 | 1.922 | .0001 | .053 |
| 42 | ----- | ----- | ----- | ---- |
| 43 | ----- | ----- | ----- | ---- |
| 44 | .0011 | 1.809 | ----- | ---- |
| 45 | ----- | ----- | ----- | ---- |
| 46 | .0006 | 1.348 | ----- | ---- |
| 47 | ----- | ----- | ----- | ---- |

General Table of Individual Observations, continued. (Amiurus)

| No. | net body wt. in grams. | length total | length trunk | head net wt. | head rel. wt. | mesonephroi net wt. | mesonephroi rel. wt. |
|---|---|---|---|---|---|---|---|
| 48 | .3727 | 31.0 | 15.0 | .0870 | 23.346 | .0074 | 1.985 |
| 49 | .3492 | 30.0 | 14.5 | .0847 | 24.255 | .0083 | 2.376 |
| 50 | .3427 | 31.0 | 15.0 | .0807 | 23.548 | .0068 | 1.984 |
| 51 | .2832 | 30.0 | 14.0 | .0609 | 21.496 | .0027 | .953 |
| 52 | .2171 | 26.0 | 12.0 | .0596 | 27.452 | .0046 | 2.118 |
| 53 | .1270 | 21.0 | 10.5 | .0441 | 34.724 | .0021 | 1.653 |
| 54 | .1143 | 20.5 | 10.0 | .0381 | 33.333 | .0015 | 1.312 |
| 55 | .0977 | 20.0 | 10.0 | .0301 | 30.808 | .0010 | 1.023 |
| 56 | .0192 | 12.0 | 6.0 | .0065 | 33.854 | ---- | ----- |
| 57 | .0167 | 9.5 | 5.5 | .0078 | 46.706 | .0001 | .598 |
| 58 | .0163 | 10.5 | 5.0 | .0075 | 45.398 | .0002 | 1.227 |
| 59 | .0154 | 10.0 | 5.0 | .0047 | 30.519 | .0002 | 1.298 |
| 60 | .0143 | 11.5 | 5.5 | .0052 | 36.363 | .0001 | .699 |
| 61 | .0137 | 11.5 | 5.5 | .0065 | 47.445 | .0001 | .729 |

| No. | brain net wt. | brain rel. wt. | eyeballs net wt. | eyeballs rel. wt. | skin net wt. | skin rel. wt. |
|---|---|---|---|---|---|---|
| 48 | .0063 | 1.690 | .0020 | .536 | .0571 | 15.320 |
| 49 | .0078 | 2.233 | .0022 | .630 | .0466 | 13.344 |
| 50 | .0079 | 2.305 | .0024 | .7003 | .0217 | 6.332 |
| 51 | .0062 | 2.188 | ---- | --- | .0255 | 9.001 |
| 52 | .0060 | 2.763 | .0017 | .783 | .0635 | 29.247 |
| 53 | .0031 | 2.440 | .0007 | .551 | .0179 | 14.094 |
| 54 | .0033 | 2.885 | .0004 | .339 | .0111 | 9.711 |
| 55 | .0028 | 2.865 | .0004 | .409 | .0114 | 11.668 |
| 56 | .0014 | 7.291 | .0003 | 1.562 | ----- | ------ |
| 57 | .0008 | 4.790 | .0002 | 1.197 | ----- | ------ |
| 58 | .0013 | 7.975 | .0003 | 1.840 | ----- | ------ |
| 59 | .0010 | 6.492 | .0002 | 1.298 | ----- | ------ |
| 60 | .0008 | 5.594 | .0003 | 2.098 | ----- | ------ |
| 61 | .0011 | 8.029 | .0004 | 2.919 | ----- | ------ |

| No. | heart net wt. | heart rel. wt. | liver net wt. | liver rel. wt. | stomach-intestines net wt. | stomach-intestines rel wt. |
|---|---|---|---|---|---|---|
| 48 | .0007 | .187 | .0119 | 3.195 | .0342 | 9.176 |
| 49 | .0014 | .400 | .0081 | 2.319 | .0275 | 7.875 |
| 50 | ---- | --- | .0212 | 6.186 | ---- | ----- |
| 51 | .0012 | .423 | .0077 | 2.717 | .0131 | 4.624 |
| 52 | .0010 | .460 | .0068 | 3.132 | .0211 | 9.718 |
| 53 | .0008 | .629 | .0039 | 3.070 | .0103 | 8.110 |
| 54 | .0001 | .087 | .0032 | 2.799 | .0073 | 6.386 |
| 55 | .0003 | .307 | .0019 | 1.944 | .0075 | 7.676 |
| 56 | .0002 | 1.041 | .0002 | 1.041 | .0015 | 7.812 |
| 57 | .0002 | 1.197 | .0002 | 1.197 | .0009 | 5.389 |
| 58 | .0002 | 1.227 | .0003 | 1.840 | .0013 | 7.975 |
| 59 | .0002 | 1.298 | .0003 | 1.941 | .0013 | 8.441 |
| 60 | .0001 | .699 | .0001 | .699 | .0015 | 10.489 |
| 61 | .0002 | 1.459 | .0002 | 1.459 | .0016 | 11.678 |

MATERIALS AND METHODS.

a. Species Examined and Description of Serial Weights and Lengths.

The materials used in this paper consisted of 47 dogfish (Mustelis canis) and 14 Amiurus. The dogfish ranged in weight from .0084 gram to 1498.8 grams, and in length from 16 mm. to 800 mm. Of the embryos, 15 weighed less than one gram, two between one and two grams, one between two and three grams, six between two and four grams, three between four and five grams, and two weighed a little more than five grams (See General Table). There is a gap in the series between the five gram embryos and the fish at or a little before birth, the next larger fish weighing 42.075 grams. Three fish weigh between forty and fifty grams, two between fifty and sixty grams, one weighs sixty five grams, one approximately 72 grams, one approximately 82 grams, one approximately 92 grams, and four weigh between 100 and 133 grams. Here again there is a gap, the next larger fish weighing 331.512 grams. Four fish weigh between 300 and 400 grams, and the largest of the series weighs 1498.8 grams. Twenty one of the dogfish were males, eighteen were females, and in nine the sex could not be ascertained. Sex was determined by the presence or absence of claspers, which structures are present in the male of the species as a partly detached portion of the medial

edge of the ventral fin. These dogfish were obtained from the Supply Dep't. of the Marine Biological Laboratory, Woods Hole, Mass.

The 14 specimens of Amiurus ranged in weight from .0137 to .3727 gram, and in length from 11.5 to 31.0 mm., the body weights presenting a fairly even series. The sex was not determined in these fish. They were also obtained from the Supply Dep't of the Marine Biological Laboratory.

b. Preservation of the specimens.

The larger dogfish (42.075 grams and up) were preserved in 5 % formalin. Formalin causes in general a swelling of the tissues, which, from data by Jackson ('09), amounted to nearly 13 % of the total volume of a human fetus of the fifth month, after three months immersion in 10 % formalin solution. Formalin is also known to cause unequal expansion of the tissues, which fact must be recognized as a source of error in relative weights of a specimen preserved in formalin. It is unlikely, however, that error from this source would be large enough to materially influence the general conclusions regarding relative growth. The embryonic dogfish and all of the Amiurus were fixed in mercuric chloride and preserved in alcohol. Alcohol causes shrinkage in the tissues, and moreover, being very volatile, would give rise to error from evaporation. To

offset this, the alcoholic specimens were soaked in water for several days before weighing. The replacement of the alcohol by water in addition to diminishing the error by evaporation, also caused the tissues to swell and regain to a certain extent their former volumes. On account of the possible changes in the various organs due to the effect of preservatives, allowance must be made for a certain amount of unavoidable error.

c. Measurements and dissecting methods.

The fish were first washed in water (if formalin-preserved) and then the total length (tip of nose to tip of tail) and trunk length (tip of nose to anus), was carefully noted. Then the gross body weight was taken and the sex noted, after which the organs and parts were dissected out and weighed. Organs not being weighed were kept on a moistened filter paper in a dish with a ground glass cover. First, the head was separated from the body just behind the mandibular arch and weighed. Then the eyeballs were removed, the extra-ocular muscles dissected off, and the optic nerve clipped close to the eyeball. The brain was removed by removing the roof of the cranium and cutting the cranial nerves close to the point where they emerge from or enter the brain . The cord was cut across posteriorly at its junction with the brain in removing the head. The heart was separated anteriorly at the junction of the conus arteriosus

and truncus arteriosus, and posteriorly at the junction of the auricle and sinus venosus. Organs having a mesentery were removed by cutting along the line of attachment of the mesentery to the organ. The stomach and intestines were weighed first with contents and then without contents, the difference being subtracted from the gross body weight to give the net body weight. The contents were usually slight in amount, however. The rectal gland was removed at the line where its duct commenced. The skin includes the skin of the entire body and the adherent subcutaneous tissue. The musculature and the skeleton (minus the few remaining structures, gills, oesophagus, etc.,) were weighed together, and then the musculature was dissected off and the skeleton and ligaments alone weighed. The difference gives the weight of the musculature. The organs and parts weighed were: brain, spinal cord, eyeballs, heart, pancreas, liver, spleen, rectal gland, mesonephroi, gonads, stomach and intestines, skin, musculature, and skeleton and ligaments. This list is more extensive than that of Kellicott, who observed only the following organs: brain, heart, pancreas, spleen, liver, gonads and rectal gland. Any apparent abnormalities were noted. In the case of an organ containing cavities, such as the heart, the cavities were thoroughly cleansed before weighing. In the specimens preserved in alcohol the blood in the heart was hardened and sometimes

could not be thoroughly removed, which accounts for some of the large variations in the weight of this organ.

In the smaller fish the weights were recorded to the ten-thousandth of a gram (tenth of a milligram), with the exception of a few instances in which the weights were recorded to the one-thousandth of a gram. In the larger fish, weights were recorded to the one-thousandth of a gram, except in the case of total body weights and structures too large to be safely weighed on such delicate balances. As a rule, however, in referring to the body weights in the following paper, the figures are carried only to the first decimal place (tenth of a gram). The percentages are likewise given, unless it is necessary to carry to further decimal places in order to give two significant figures. The organs were first rolled gently on filter paper to remove superfluous moisture and were then placed in a closed dish for weighing to prevent loss by evaporation.

DISCUSSION OF DATA

To reduce the range of individual variation and thus give a more nearly correct idea of the average relative size of the parts and organs at various periods, figures representing the averages of several individuals of approximately the same body weight are used largely instead of considering each individual separately.

The group of dogfish whose body weights range between

42 and 82 grams, are considered to represent approximately the conditions found at birth. All these fish appeared to be free living. Kellicott found the average weight of 13 dogfish at birth to be 76.2 grams (maximum 84, minimum 69.5 grams). These fish were born from a single female weighing 8434 grams and this also is the maximum number of young recorded for this fish; so Kellicott says the weights may not represent the precise conditions found at birth.

1. Growth of the Head.

RELATIVE GROWTH OF THE HEAD

table one

| No. of specimens | Av. net body weight | Av. actual head weight | Av. percentage head weight | |
|---|---|---|---|---|
| 3 | .0346 grams | .0094 grams | 26.0 | dogfish embryos |
| 3 | .0854 | .0332 | 38.9 | |
| 6 | .3109 | .0963 | 30.8 | |
| 3 | .6993 | .1975 | 28.6 | |
| 2 | 1.4410 | .2111 | 22.7 | |
| 1 | 2.6060 | .5072 | 19.5 | |
| 6 | 3.7493 | .8655 | 23.1 | |
| 5 | 4.9723 | 1.0419 | 17.6 | |
| 1 | 42.0750 | 8.1380 | 19.3 | young dogfish |
| 3 | 49.8720 | 8.8130 | 17.7 | |
| 2 | 62.3900 | 10.4710 | 16.8 | |
| 1 | 72.3500 | 11.6407 | 16.1 | |
| 1 | 82.1100 | 13.8810 | 16.9 | |
| 1 | 92.7900 | 15.3930 | 16.6 | |
| 1 | 102.3950 | 17.6280 | 17.2 | |
| 3 | 128.7170 | 18.4700 | 14.3 | |
| 4 | 347.1360 | 42.0570 | 12.1 | |
| 1 | 1498.8000 | 193.0000 | 12.9 | |
| 7 | .0276 | .0097 | 38.7 | Amiurus |
| 2 | .1206 | .0411 | 34.0 | |
| 2 | .2502 | .0602 | 24.5 | |
| 3 | .3548 | .0841 | 23.7 | |

An inspection of the accompanying table of averages shows, as has been repeatedly observed in many different species of animals, that the head is relatively largest early in embryonic life. In the series of fish under discussion, three dogfish embryos with an average body weight of .0346 gram have an average percentage head weight of 26 %. In an average of three slightly larger fish weighing about .0854 gram the average percentage head weight is 38.9 %, an increase of nearly 13 %. The percentage now decreases, at first sharply and then more gradually, to 19.5 % in an individual with a body weight of 2.6 grams. From here it rises unexpectedly to 23 % in an average of six specimens with an average body weight of 3.7 grams. The average relative weight of both the eyeballs and the brain also rises at this point. The percentage weight of the head now drops to an average of 17.6 % in five individuals haveing an average body weight of 5.0 grams. Thus on the whole, the relative weight of the head in this series of dogfish becomes less as the fish increases in body weight.

In the case of the young dogfish, the table of averages and the accompanying curve of growth indicate that in general, the percentage weight of the head decreases with age. The variations that exist are small and are observations on single individuals. The percentage weight at about birth is 17.5 %. The highest percentage weight on the curve

is 19.3 %, the body weight being 42.0 grams. This is an observation on a single individual, so that the chance of variation is large. From this point on the curve, the percentage weight drops rapidly to 12.1 % in an average of four individuals with an average body weight of 347 grams. The three fluctuations that exist in the curve during this fall are determined by observations on single individuals, and may represent individual variations. The largest fish weighed 1498.8 grams and had a percentage head weight of 12.9 %. Kellicott's ('08) data do not include the head.

Seven Amiurus having an average body weight of .0276 gram have an average relative head weight of 38.7 %. As the body weight increases, the percentage weight of the head drops to an average of 23.7 % in three individuals with an average body weight of .3548 gram.

From the above series of data it is evident that the percentage weight of the head is highest in the early stages of embryonic growth; that in general it may be said that the head becomes relatively smaller with age. Jackson has found this true in the human embryo, the head reaching its maximum relative size of about 45 % of the total body volume during the latter half of the second month. Lowrey finds the same thing true in the pig, the 15 mm. pig having a relative head weight of 26.36 % and the 18 mm. pig a relative head weight of 29.69 %. The relative head weight of the pig

thereafter decreases to 6.26 % of the total body weight in the adult. The adult human head forms about 6 to 9 % of the total body weight. The adult dogfish has a percentage head weight of about 12 %. The maximum relative size of the head in the dogfish was 40.5 % in a fish weighing .0916 gram. Thus, as in the case of the human species, the head increases in relative size early in embryonic life. Jackson and Lowrey have observed in the white rat that the head increases in relative size shortly after birth, reaching its maximum in the second week. So far as I have been able to ascertain, this is the only species in which this has been observed.

2. Relative Growth of Systems.

a. Skin.

RELATIVE GROWTH OF THE SKIN
table two

| No. of specimens | Av. net body weight | Av. actual skin weight | Av. percentage skin weight | |
|---|---|---|---|---|
| 3 | .3720 g. | .0230 g. | 6.2 | dogfish embryos |
| 3 | .6993 | .0417 | 5.5 | |
| 2 | 1.4410 | .0743 | 5.3 | |
| 1 | 2.6060 | .2272 | 8.7 | |
| 6 | 3.7493 | .2755 | 7.3 | |
| 5 | 4.9722 | .3518 | 7.1 | |
| 1 | 42.0750 | 3.9910 | 9.5 | young dogfish |
| 3 | 49.8720 | 6.0400 | 12.2 | |
| 2 | 62.3900 | 7.7780 | 12.5 | |
| 1 | 72.3500 | 8.5527 | 11.8 | |
| 1 | 82.1100 | 7.2460 | 8.8 | |
| 1 | 92.7900 | 13.4840 | 14.5 | |
| 1 | 102.2950 | 12.5710 | 12.3 | |
| 3 | 128.7170 | 11.9950 | 9.3 | |
| 4 | 347.1360 | 29.9820 | 8.7 | |
| 1 | 1498.8000 | 109.0070 | 7.3 | |
| 1 | .0977 | .0114 | 11.7 | Amiurus |
| 2 | .1206 | .0145 | 11.9 | |
| 2 | .2502 | .0445 | 19.1 | |
| 3 | .3548 | .0418 | 11.7 | |

Dissection of the skin in small fish embryos is difficult, and the liability of error greater than in some of the other measurements.

In the accompanying growth tables and curves, it is evident that the growth of the skin is rather variable. In the embryo of about .37 gram, it forms an average of 6.2 % of the total body weight; the relative weight of the skin decreases from this point until in three individuals of about 1.44 grams it averages only 5.3 %. From here it rises to 8.7 % in an individual weighing 2.6 grams, and then again falls gradually to 7.1 % in an average of five fish weighing about 5.0 grams.

In the young dogfish the percentage weight of the skin is 9.5 % in a fish weighing 42.0 grams. From here it rises to about 12 % in fish weighing between 49 and 72 grams. Then it drops suddenly to 8.8 % in a fish weighing 82 grams, and rises again to 14.5 % in a fish weighing 92.8 grams. These two fluctuations probably do not represent the average condition, since the points are determined by data on single individuals. From 14.5 % the relative weight of the skin drops quickly to 9.3 % in an average of three individuals weighing about 128.7 grams. Then it drops very gradually to 7.3 % in the fish weighing 1498.8 grams.

In Amiurus, the percentage weight of the skin in

seven fish with an average body weight of .028 gram is 11.7 %. From here the curve rises at first slowly and then more rapidly to an average of 19 % in two fish weighing about .25 gram. Then it drops to 11.7 % in an average of three fish weighing about .35 gram.

The above figures indicate that the percentage weight of the skin is higher in Amiurus than in the dogfish of the same weight. It is also evident that the skin is relatively heavier in the dogfish just after birth than in either adult or embryonic life. Jackson and Lowrey find that the relative weight of the skin of the white rat increases during the first week after birth and then decreases. In their paper they say that this increase is not due to the development of the hair coat, for it develops later; and that it apparently is not due to an unusual accumulation of fat in the subcutaneous tissue. Possibly the change in environment from the protecting uterus of the mother to the more rigorous post natal conditions would stimulate the skin of the new-born animal to a higher rate of relative growth.

b. Skeleton (including cartilages and ligaments)

(see next page for table)

The smallest dogfish embryo in which the percentage weight of the skeleton was determined weighed 2.6 grams, and the relative weight of the skeleton was 7.8 %. In a heavier individual with a body weight of 3.8 grams, the

RELATIVE GROWTH OF THE SKELETON
table three

| No. of specimens | Av. net body weight | Av. actual skel. weight | Av. percentage skeleton wt. | |
|---|---|---|---|---|
| 1 | 2.6060 g. | .2032 g. | 7.8 | dogfish embryos |
| 1 | 3.8260 | .1722 | 4.5 | |
| 2 | 5.1460 | .2790 | 5.5 | |
| 1 | 42.0750 | 3.4750 | 8.3 | young dogfish |
| 3 | 49.8740 | 3.4990 | 7.0 | |
| 1 | 65.6200 | 5.9060 | 9.0 | |
| 1 | 72.3500 | 7.6357 | 10.6 | |
| 1 | 82.1100 | 6.8490 | 8.3 | |
| 1 | 92.7900 | 7.9310 | 8.5 | |
| 1 | 102.2950 | 9.0590 | 8.9 | |
| 3 | 128.7170 | 12.1400 | 9.4 | |
| 4 | 347.1360 | 32.0680 | 9.3 | |
| 1 | 1498.8000 | 136.3000 | 9.1 | |

percentage weight of the skeleton was 4.5 %. Two individuals averaging 5.1 grams in body weight had an average percentage skeleton weight of 5.5 %. The data on the embryos are meagre and variable, but seem to indicate that the percentage weight of the skeleton is smaller than in the later stages.

In the young dogfish the data on the skeleton are somewhat more complete. In an individual weighing 42 grams the percentage weight of the skeleton was 8.3 %. In the next three individuals the body weight is 50 grams, and the percentage weight of the skeleton 7.0 %. From here the curve goes rapidly up to a maximum of 10.6 % in an individual weighing 72 grams. Then the percentage weight of the skeleton drops to 8.3 % in an 82 gram fish. Then it rises to 9.4 % in three fish weighing 129 grams, and again falls gradually to 9.1 % in a 1499 gram fish. These figures

indicate that, sometime early in life, the percentage weight of the skeleton is higher in the dogfish than it is later when the fish is full grown. This perhaps is due to the fact that the free living fish is much more active than the embryo, and this activity is a stimulus to the production of a heavier skeleton. Later, with the more rapid growth of other parts, the skeleton lags behind. This increase probably comes shortly after birth, though at what time it is impossible to say from the accompanying data.

Jackson and Lowrey find that in the white rat the skeleton increases relatively for a short time after birth, the average percentage being 17.27 % at birth and 18.47 % at one week; thereafter it diminishes steadily to an adult figure of 10.91 %. Welcker and Brandt find the relative weight of the skeleton in fishes to be from 6 to 17 %, in amphibia from 7 to 10 %, in reptiles from 7 to 43 % and in birds 7 to 13 %. The skeleton is variable in fishes; in the dogfish it runs from 7 to 10 % after birth, while Welcker and Brandt find that in the stickling it is 16.97 % in the adult. The figure is higher in the stickling because of the well developed exoskeleton. The variability in the skeleton in poorly nourished animals would naturally be large, and it also would be greater than the variability in most of the other parts, since the absolute weight would be less affected. Mühlmann estimates the relative weight of the human newborn

to be 12.6 %, increasing to 20.4 % from 11 to 20 years, and decreasing to 10.1 % in old age.

c. Musculature

RELATIVE GROWTH OF THE MUSCULATURE
table four

| No. of specimens | Av. net body weight | Av. actual wt. musculature # | Av. per cent wt. musculature | |
|---|---|---|---|---|
| 6 | .3109 g. | .1424 g. | 45.9 | dogfish embryos |
| 3 | .6993 | .2771 | 39.5 | |
| 2 | 1.4410 | .6099 | 42.1 | |
| 1 | 2.6060 | 1.1862 | 45.5 | |
| 6 | 3.7493 | 1.6085 | 42.7 | |
| 5 | 4.9722 | 2.0971 | 32.4 | |
| 3 | 49.8740 | 23.6700 | 47.6 | young dogfish |
| 1 | 65.6200 | 31.9050 | 48.6 | |
| 1 | 72.3500 | 26.4357 | 36.5 | |
| 1 | 82.1100 | 40.0870 | 48.8 | |
| 1 | 92.7900 | 49.8550 | 53.7 | |
| 1 | 102.2950 | 49.3270 | 48.2 | |
| 3 | 128.7170 | 52.5470 | 40.4 | |
| 4 | 347.1360 | 201.8060 | 58.1 | |
| 1 | 1498.8000 | 939.6000 | 63.0 | |

# in the case of the embryos in the above table, the musculature is considered plus the skeleton.

Owing to the difficulty of dissecting out the skeleton in such small fish, the musculature and skeleton were weighed together in most of the embryos, and to make the percentages comparable, the percentage weight of the musculature is considered plus the skeleton in all of the embryos. This makes the figure higher than that for the musculature alone, which must be borne in mind.

In an average of 6 dogfish embryos the body weight is .31 gram, and the percentage weight of the musculature and skeleton 45.9 %. Then it drops to 39.5 % in 3 individuals

with an average body weight of .6993 gram. From here it rises to 45.5 % in a fish weighing 2.6 grams. Then it drops to 32.4 % in five fish with an average body weight of 4.9 grams.

In the young dogfish the musculature is considered apart from the skeleton. In three fish having an average body weight of 50 grams, the percentage weight of the musculature is 47.6 %. From here it rises slightly to 48.6 % in an individual weighing 65.6 grams. Then it falls sharply to 36.5 % in an individual weighing 72 grams and again rises steadily to 53.7 % in a fish weighing 92 grams. Then it drops to 40.4 % in an average of three fish weighing 128 grams. From here it rises rather sharply to 58.1 % in an average of 4 fish weighing 347 grams, and then more slowly to 63 % in a fish weighing 1499 grams.

From the above data it is evident that in general, the relative weight of the musculature of the dogfish embryo (for the fish observed) is somewhat smaller than at birth. Also that after birth the musculature tends in general to increase in relative weight. Compared with other animals, the dogfish has a very large proportion of musculature.

In the white rat Jackson and Lowrey have found that the musculature is about 24.4 % of the total body at birth. This percentage decreases to 22.8 % at 1 week, and there-

after increases to 45 % in the adult rat. For the human new born, Mühlmann estimates the percentage weight of the musculature to be 22.4 %, increasing to 43.2 % at 41 to 50 years, and thereafter decreasing to 18.6 % in old age. In the dogfish the musculature probably increases in percentage weight thruout life. This is due to the fact that the dogfish does not reach a definite adult condition such as that found in mammals. Growth continues (according to Kellicott) until the animal dies. In reptiles, Welcker and Brandt find the percentage weight of the musculature to vary from 19 to 57 %, in amphibia, from 43 to 54 % and in fishes from 49 to 59 %.

d. Viscera (as a whole)

RELATIVE GROWTH OF THE VISCERA
table five

| No. of specimens | Av. net body weight | Av. rel. wt. viscera | |
|---|---|---|---|
| 3 | .3390 grams | 18.9 | dogfish embryos |
| 2 | .6758 | 19.2 | |
| 2 | 1.4410 | 17.0 | |
| 1 | 2.6060 | 14.0 | |
| 5 | 3.7959 | 14.4 | |
| 3 | 4.8730 | 15.2 | |
| 1 | 42.0750 | 12.0 | young dogfish |
| 2 | 48.1890 | 14.4 | |
| 2 | 62.3900 | 11.5 | |
| 1 | 72.3500 | 10.6 | |
| 1 | 92.7900 | 12.1 | |
| 1 | 102.2950 | 12.7 | |
| 3 | 128.7170 | 12.1 | |
| 4 | 347.1360 | 14.3 | |
| 1 | 1498.8000 | 9.8# | |

# minus pancreas

Under this head are included the central nervous system, thoracic and abdominal viscera. The percentage is computed by adding the percentage weights of the individual organs.

In an average of 3 dogfish embryos the body weight is .34 gram, and the percentage weight of the viscera 18.9 %. This percentage rises to 19.2 % in 2 individuals having an average body weight of .67 gram. In the average of the next group of two fish, the body weight is 1.44 grams and the percentage weight of the viscera 17 %. The next fish weighs 2.6 grams, and the percentage weight of the viscera is 14 %. From here the percentage rises slightly to 14.4 % in 5 fishes having an average body weight of 3.7 grams. In the average of the next three fish the body weight is 4.8 grams and the visceral percentage 15.2 %. The foregoing figures indicate that the visceral group in the earlier embryos is relatively large, but that it diminishes in relative size as growth progresses. In the earlier embryos the high figure is due to the high percentage weight of the central nervous system at this period. As the central nervous system grows relatively smaller, some of the other organs (principally mesonephros) grow relatively larger but do not counterbalance the drop in the nervous system.

In the young dogfish the percentage weights of the

viscera at about birth are somewhat lower than in the embryos observed. In a fish weighing 42 grams the relative weight of the viscera is 12 %. In the next larger fish the body weight is 47 grams and the relative weight of the viscera is 13.5 %. In an average of two larger fish the body weight is 62 grams and the percentage weight of the viscera 11.5 %. The next fish weighs 72 grams, of which weight the viscera form 10.6 %. (The foregoing fish are at or about birth, and in an average of the entire group the percentage weight of the viscera is 12.1 %.) In the next group of averages, the percentage weight of the viscera in fishes whose body weights range from 92 to 129 grams remains constantly a little over 12.%. In an average of the next group of three fish the body weight is 347 grams and the relative weight of the viscera 14.3 %. This figure declines to 9.8 % in a fish weighing 1499 grams.

From the accompanying curves it may be seen that the visceral percentage is relatively high in the earlier stages of the embryo and that it drops as the general growth of the embryo progresses. At about birth the percentage has dropped to about 12.1 %. In general, the percentage increases after birth to a certain point (14.3 % in 347 gram fish) and thereafter decreases. Percentage weights of the viscera im the adult dogfish are variable on account of the variability of the liver, in which, as Kellicott has observ-

ed, the variability is due to the amount of fat present in the organ. In the white rat, Jackson and Lowrey find the visceral percentage at birth to be 18.05 %, which figure increases to a maximum of 21.28 % at three weeks and thereafter decreases to 13.3 % at one year. This corresponds in general with the visceral growth in the dogfish. The following percentages have been calculated from data by Welcker and Brandt: fish, 11.19 % to 16.30 %; amphibia, 11.57 % to 16.61 %; reptiles, 5.72 % to 18.34 %. A visceral percentage of 15.79 % (without gonads, kidneys, spinal cord, pancreas and spleen) has been calculated from data by Welcker and Brandt on an average of six Salamandra Maculosa embryos having an average body weight of .1678 gram. An average of two specimens on the third day (minus the same organs) shows a visceral percentage of 23.11 %. An average of three adults (minus the same organs and the gills) shows a visceral percentage of 14.26 %. In the human newborn the viscera average about 24 % of the body weight (Jackson). Vierordt finds it about 23.4 % for the newborn and 9.8 % for the adult.

Relative Growth of Individual Organs

a. Brain

(see next page for table)

The relative size of the brain is high in the early dogfish embryo, but decreases thru embryonic as well as

RELATIVE GROWTH OF THE BRAIN
table six

| No. of specimens | Av. net body weight | Av. actual brain weight | Av. per cent brain weight | |
|---|---|---|---|---|
| 6 | .0600 g. | .0063 g. | 11.4 | dogfish embryos |
| 6 | .3109 | .0227 | 7.3 | |
| 3 | .6993 | .0451 | 6.6 | |
| 2 | 1.4410 | .0483 | 3.6 | |
| 1 | 2.6060 | .0662 | 2.5 | |
| 6 | 3.7493 | .0986 | 2.6 | |
| 5 | 4.9722 | .1069 | 2.2 | |
| 1 | 42.0750 | .7860 | 1.9 | young dogfish |
| 3 | 49.8720 | .8690 | 1.8 | |
| 2 | 62.3900 | .9110 | 1.5 | |
| 1 | 72.3500 | .9457 | 1.3 | |
| 1 | 82.1100 | 1.0730 | 1.2 | |
| 1 | 92.7900 | 1.2280 | 1.3 | |
| 1 | 102.2950 | 2.3000 | 2.2 | |
| 3 | 128.7170 | 1.5990 | 1.2 | |
| 4 | 347.1360 | 2.3740 | .69 | |
| 1 | 1498.8000 | 6.2980 | .42 | |
| 7 | .0276 | .0013 | 6.1 | Amiurus |
| 2 | .1206 | .0032 | 2.7 | |
| 2 | .2502 | .0061 | 2.5 | |
| 3 | .3548 | .0073 | 2.1 | |

postnatal life. In six embryos having an average body weight of .06 gram, the percentage weight of the brain is 11.4 %. In general, this decreases in the embryos observed, at first rapidly and then more slowly to an average of 2.2 % in five fish having an average body weight of 4.9 grams.

At birth the percentage weight of the brain is between one and two per cent. Kellicott finds it to be 1.116 %, which percentage decreases at first rapidly and then more slowly thruout life. Although there are some fluctuations, (the percentage weight of 2.2 % recorded for an individual

weighing 102 grams is probably either an error or an abnormality) my data (for the weights observed) show the same decrease. In a fish weighing 42 grams the percentage weight of the brain is 1.9 %; in a fish weighing 1499 grams it is .42 %.

In Amiurus the percentage weight of the brain drops from 6.1 % in seven fish with an average body weight of .0276 gram to 2.1 % in three fish with an average body weight of .3548 gram. Thus the brain is relatively lighter than in the dogfish embryo of the same size.

Relative weight of the brain has been more extensively studied than that of any other organ, and in general, has always been found to decrease with increase in body weight. Jackson ('09) finds that in the early human embryo the brain increases in relative weight to a maximum of 20 % in the second month, thereafter decreasing to an average of 12.8 % in the still-born, and 14.6 % in the live-born fetus. Lowrey finds this in the early pig embryo, the brain attaining a maximum relative weight of 9 % at 18 millimeters, thereafter decreasing to about 4 % at term and .087 % in the adult. Jackson ('13) finds the maximum postnatal relative size of the brain in the white rat to occur, not at birth, but a short time later, reaching 6.7 %. Vierordt estimates the percentage weight of the brain in the new-born human to be 12.29 %, which figure decreases to 2.16 % for the

adult. Welcker and Brandt give data on the relative brain weight showing ranges as follows: of fishes, .07 % to 1.49 %; amphibia, .17 % to .42 %; reptiles, .04 % to .61 %.

b. Spinal Cord

RELATIVE GROWTH OF THE SPINAL CORD
table seven

| No. of specimens | Av. net body weight | Av. net wt. spinal cord | Av. rel. wt. spinal cord | |
|---|---|---|---|---|
| 1 | .1867 grams | .0033grams | 1.77 | dogfish embryos |
| 4 | .3572 | .0029 | .83 | |
| 2 | .6758 | .0041 | .62 | |
| 2 | 1.4410 | .0074 | .44 | |
| 1 | 2.6060 | .0062 | .24 | |
| 5 | 3.7959 | .0088 | .24 | |
| 4 | 4.7503 | .0166 | .34 | |
| 1 | 42.0750 | .2090 | .50 | young dogfish |
| 3 | 49.8740 | .2210 | .44 | |
| 2 | 62.3900 | .2230 | .36 | |
| 1 | 72.3500 | .3157 | .44 | |
| 1 | 82.1100 | .2840 | .35 | |
| 1 | 92.7900 | .3480 | .38 | |
| 1 | 102.2950 | .3330 | .33 | |
| 3 | 128.7170 | .5160 | .40 | |
| 4 | 347.1360 | .9060 | .26 | |
| 1 | 1498.8000 | 2.4970 | .17 | |

An inspection of the table of growth of the spinal cord of the embryonic dogfish will show that the spinal cord is relatively large in the early embryo. In a fish weighing .1867 gram, the relative weight of the spinal cord is 1.76 %. From here it falls at first rapidly and then more slowly to .24 % in five fish with an average body weight of 3.7 grams. Finally it rises to .34 % in four embryos with an

average body weight of 4.75 grams.

At some stage between the embryos examined and birth, the relative weight of the cord apparently rises, for in a fish weighing 42 grams it is .50 %. As the body weight of the young dogfish increases, the relative weight of the cord fluctuates but on the whole diminishes, and finally drops steadily to .17 % im a fish weighing 1499 grams.

In the human embryo, Jackson ('09) finds that in the fifth week the percentage weight of the cord is 4.85 %, and that it diminishes at first rapidly and then more slowly, to about .15 % at birth. Vierordt gives .18 % for the relative weight of the cord at birth and .06 % for the adult. In the pig, Lowrey finds the relative weight of the cord to decrease from 1.87 % at 18 mm. to .33 % at birth and to .04 % in the adult. Welcker and Brandt give data on the relative weight of the spinal cord showing ranges as follows: fishes, .04 % to .29 %; amphibia, .10 % to .35 %; reptiles, .04 % to .70 %. In their observations on amphibia and reptiles, Welcker and Brandt find that the cord approaches or exceeds the brain in relative weight. In the dogfish embryo the spinal cord is usually only about one tenth as large as the brain, while in the adult it is about one third as large.

c. Eyeballs

(see next page for table)

RELATIVE GROWTH OF THE EYEBALLS
table eight.

| No. of specimens | Av. net body weight | Av. net wt. eyeballs | Av. rel. wt. eyeballs | |
|---|---|---|---|---|
| 5 | .0618 g. | .0040 g. | 5.6 | dogfish embryos |
| 6 | .3109 | .0166 | 5.3 | |
| 3 | .6993 | .0368 | 5.3 | |
| 2 | 1.4410 | .0541 | 3.9 | |
| 1 | 2.6060 | .0752 | 2.9 | |
| 6 | 3.7493 | .1682 | 4.5 | |
| 5 | 4.9722 | .1941 | 3.9 | |
| 1 | 42.0750 | 1.1340 | 2.7 | young dogfish |
| 3 | 49.8720 | 1.1440 | 2.3 | |
| 2 | 62.3900 | 1.2510 | 2.0 | |
| 1 | 72.3500 | 1.0297 | 1.4 | |
| 1 | 82.1100 | 1.7810 | 2.2 | |
| 1 | 92.7900 | 1.2360 | 1.3 | |
| 1 | 102.2950 | 2.1300 | 2.1 | |
| 3 | 128.7170 | 2.3830 | 1.8 | |
| 4 | 347.1360 | 3.8990 | 1.1 | |
| 1 | 1498.8000 | 9.5410 | .64 | |
| 7 | .0276 | .0003 | 1.6 | Amiurus |
| 2 | .1206 | .0005 | .45 | |
| 1 | .2171 | .0017 | .78 | |
| 3 | .3548 | .0033 | .62 | |

In the early dogfish embryo (five specimens with an average body weight of .0618 gram) the relative weight of the eyeballs attains a maximum of 5.6 %. This percentage drops steadily to 2.9 % in a fish weighing 2.6 grams. From here it rises to 4.5 % in six embryos with an average body weight of 3.7 grams and then drops again. At birth it is 2.1 %.

In the young dogfish, the relative weight of the eyeballs drops from about 2.1 % at birth to 1.1 % in four fish averaging 347 grams in body weight. At 1500 grams

body weight, the eyeballs form about .64 % of the body, being as large as the brain and spinal cord combined.

In Amiurus the eyeballs are relatively smaller than in dogfishes of a corresponding body weight. In seven Amiurus having an average body weight of .0276 gram, the relative weight of the eyeballs is 1.6 %. This percentage drops to .45 % in an average of two fish with an average body weight of .1206 gram. Then it rises to .78 % in a fish weighing .2502 gram and falls again to .62 % in three fish averaging .3548 gram in weight. The curve of relative growth of the eyeballs of Amiurus resembles that for the eyeballs of the dogfish embryo.

In the pig, Lowrey finds that the eyeballs reach a maximum of 1.15 % in relative size when the embryo is 86 mm. in length, decreasing to .41 % at birth and to .011 % in the adult. In three human fetuses of about the sixth month, Jackson ('09) finds the eyeballs to form .45 %, .40 %, and .39 % of the total body weight. According to Vierordt, the eyeballs form .24 % of the total body weight at birth and .02 % in the adult. Welcker and Brandt give data on percentage weight of the eyeballs showing the following ranges: fishes, .17 % to 2.52 %; amphibia, .56 % to .85 %; reptiles, .02 % to .56 %. The above comparisons show the eyeballs of the dogfish embryo to be unusually large in relative size.

d. Heart

RELATIVE GROWTH OF THE HEART
table nine

| No. of specimens | Av. net body weight | Av. net wt. heart | Av. rel.wt. heart | |
|---|---|---|---|---|
| 4 | .0544 g. | .0007 g. | 1.94 | dogfish embryos |
| 4 | .3170 | .0017 | .59 | |
| 3 | .6993 | .0023 | .32 | |
| 2 | 1.4410 | .0075 | .48 | |
| 1 | 2.6060 | .0132 | .51 | |
| 6 | 3.7493 | .0098 | .27 | |
| 4 | 4.9003 | .0122 | .25 | |
| 1 | 42.0750 | .0760 | .18 | young dogfish |
| 3 | 49.8720 | .0780 | .16 | |
| 2 | 62.3900 | .0980 | .16 | |
| 1 | 72.3500 | .0777 | .11 | |
| 1 | 82.1100 | .1650 | .20 | |
| 1 | 92.7900 | .1940 | .21 | |
| 1 | 102.2950 | .1760 | .17 | |
| 3 | 128.7170 | .2470 | .19 | |
| 4 | 347.1360 | .6710 | .18 | |
| 1 | 1498.8000 | 3.0030 | .20 | |
| 7 | .0276 | .0002 | 1.03 | Amiurus |
| 2 | .1206 | .0004 | .36 | |
| 2 | .2502 | .0011 | .44 | |
| 2 | .3609 | .0010 | .29 | |

In the early stages of embryonic life, the heart of the dogfish has a percentage weight of 1.94 %. Earlier stages might show a higher maximum. This high percentage falls rapidly, until in three fish having an average body weight of .6993 gram it is .32 %. Then it rises to .51 % in a fish weighing 2.6 grams, and finally falls to .21 % in four fish averaging 4.9 grams in body weight.

In the dogfish at birth, Kellicott finds the average relative weight of the heart to be .11 %. In the series

presented in this paper (which are of course subject to variation from the small number of observations) the relative weight of the heart at about birth is somewhat higher, being .15 %. (This percentage may be higher than Kellicott's from the fact that he did not weigh the complete heart, but only the ventricle and conus arteriosus.) Shortly after birth the percentage weight of the heart rises slightly, reaching a maximum of .21 % in an individual weighing 92 grams. From here it falls with some fluctuations, to .18 % in four fish with an average body weight of 347 grams. Then it rises slightly to .2 % in a fish weighing 1499 grams. This last figure is probably too high, since Kellicott, in a larger series, finds the percentage weight of the heart in fish of this size to be .087 %.

In Amiurus the percentage weight of the heart in seven fishes with an average body weight of .0276 gram, is 1.03 %. In two individuals with an average body weight of .1206 gram, this percentage has decreased to .36 %. From here the curve rises slightly and then drops to .29 % in two fish averaging .35 gram in body weight.

In the early human embryo, Jackson ('09) has estimated the relative weight of the heart to be more than 5 % of the total body. He finds that it decreases rapidly and reaches about .7 % at birth. In the newborn, Vierordt estimates the relative weight of the heart to be .76 %, and in the adult,

.46 %. Lowrey finds the curve of growth of the embryonic and adult pig heart to be similar to that of the human. Welcker and Brandt give data on percentage weight of the heart showing ranges as follows: of fishes, .12 % to .38 %; amphibia, .26 % to .43 %; reptiles, .23 % to .56 %.

e. Pancreas

RELATIVE GROWTH OF THE PANCREAS
table ten

| No. of specimens | Av. net body weight | Av. net wt. pancreas | Av. rel. wt. pancreas | |
|---|---|---|---|---|
| 6 | .3109 g. | .0002 g. | .072 | dogfish embryos |
| 3 | .6993 | .0005 | .069 | |
| 2 | 1.4410 | .0007 | .055 | |
| 1 | 2.6060 | .0009 | .034 | |
| 6 | 3.7493 | .0026 | .069 | |
| 3 | 4.8730 | .0031 | .064 | |
| 1 | 42.0750 | .0320 | .076 | young dogfish |
| 1 | 47.5440 | .0380 | .079 | |
| 2 | 62.3900 | .0350 | .057 | |
| 1 | 72.3500 | .0227 | .031 | |
| 1 | 82.1100 | .0630 | .076 | |
| 1 | 92.7900 | .0580 | .062 | |
| 1 | 102.2950 | .0650 | .063 | |
| 3 | 128.7170 | .1510 | .116 | |
| 4 | 347.1360 | .4870 | .140 | |

The pancreas in the embryos weighed was relatively small, forming in six fish with an average body weight of .3109 gram, .072 % of the total body weight. This falls gradually to .034 % in a fish weighing 2.6 grams. In three fish averaging 4.9 grams in body weight the percentage weight of the pancreas is .064 %.

In the young dogfish the pancreas forms at about birth approximately .06 % of the body weight. In a group of four

fish averaging 347 grams in body weight, the percentage weight of the pancreas has increased to .14 %.

Kellicott finds the percentage weight of the pancreas in the dogfish at birth to be .08 %; this, he says, increases to a maximum of .137 % in fish weighing about 200 grams, and decreases thereafter to about .075 %. In the human embryo, Jackson finds the percentage weight of the pancreas small at first, being .032 % in a specimen of the sixth week, while at birth it is .145 % in the live born. Vierordt gives .11 % of the total body weight for the pancreas in the newborn, and .15 % for the adult. Lowrey finds the curve of relative growth of the pancreas in the pig similar to that of the human. Welcker and Brandt give data on the relative weight of the pancreas showing the following ranges: of amphibia, .08 % to .17 %; reptiles, .04 % to .29 %.

f. Liver

(see next page for table)

In the earlier stages of embryonic life the liver of the dogfish is relatively small, forming in 4 fish with an average body weight of .0752 gram but 2.4 % of the total body weight. This percentage rises very suddenly to 5.8 % in six fish with an average body weight of .3109 gram and then falls very gradually to 4.6 % in five embryos with an average body weight of 4.9 grams.

RELATIVE GROWTH OF THE LIVER
table eleven

| No. of specimens | Av. net body weight | Av. net wt. liver | Av. rel. wt. liver | |
|---|---|---|---|---|
| 4 | .0752 g. | .0017 g. | 2.4 | dogfish embryos |
| 6 | .3109 | .0180 | 5.8 | |
| 3 | .6993 | .0382 | 5.4 | |
| 2 | 1.4410 | .0818 | 5.6 | |
| 1 | 2.6060 | .1285 | 4.9 | |
| 6 | 3.7493 | .1719 | 4.6 | |
| 5 | 4.9722 | .2302 | 4.6 | |
| 1 | 42.0750 | 1.8130 | 4.3 | young dogfish |
| 3 | 49.8720 | 2.3580 | 4.8 | |
| 2 | 62.3900 | 3.5380 | 5.7 | |
| 1 | 72.3500 | 3.2497 | 4.5 | |
| 1 | 82.1100 | 5.2390 | 6.4 | |
| 1 | 92.7900 | 5.4310 | 5.9 | |
| 1 | 102.2950 | 5.5060 | 5.4 | |
| 3 | 128.7170 | 5.6230 | 4.4 | |
| 4 | 347.1360 | 24.0010 | 6.9 | |
| 1 | 1498.8000 | 88.1000 | 5.9 | |
| 7 | .0276 | .0004 | 1.4 | Amiurus |
| 2 | .1206 | .0035 | 2.9 | |
| 2 | .2502 | .0072 | 2.9 | |
| 3 | .3548 | .0137 | 3.9 | |

At about birth the percentage weight of the liver is 4.8 %. This is somewhat higher than the figure (3.12 %) given by Kellicott. This, of course, may be due to the smaller number of specimens in this series. After birth the relative weight of the liver apparently rises to a maximum of 6.9 % in four fish with an average body weight of 347 grams. In a fish weighing 1499 grams this has decreased to 5.9 % of the total body weight.

In Amiurus the percentage weight of the liver rises from 1.4 % in seven fish with an average body weight of

.0276 gram to 3.9 % in three fish with an average body weight of .3548 gram.

The relative seze of the liver in the dogfish is variable. Kellicott thinks that this variability is due to the presence of fat in the organ. He finds that in livers of high percentage weight the percentage of fat is also higher, and vice versa. In the human embryo, figures by Jackson show that the liver attains a higher maximum of percentage weight than in the dogfish, reaching about 7.5 % in the second ant third months. At birth the percentage is decreasing but is still higher than in the dogfish, being 5.23 % in the live-born (Jackson). In the adult, Vierordt estimates that the liver forms 2.75 % of the total body weight. In six of the largest fish he measured, Kellicott finds the percentage weight of the liver to be 5.5 %, considerably more than in the human adult. In the liver of the albino rat, Jackson finds the percentage weight to decrease from 4.74 % at birth to 3.39 % at seven days, thereafter increasing to a maximum of 6.78 % at six weeks. This author finds the variability of the liver of the albino rat to be large and irregular. In the pig embryo, Lowrey finds the liver to reach a maximum of 15.88 % of the total body weight at 25 millimeters. Welcker and Brandt give data on the percentage weight of the liver with ranges as follows: of fishes, 1.57 % to 3.85 %; amphibia, 2.63 % to 6.79 %; reptiles, 3.33 % to 5.78 %.

g. Spleen

RELATIVE GROWTH OF THE SPLEEN
table twelve

| No. of specimens | Av. net body weight | Av. net wt. spleen | Av. rel. wt. spleen | |
|---|---|---|---|---|
| 6 | .3109 g. | .00016 g. | .052 | dogfish embryos |
| 3 | .6993 | .0004 | .055 | |
| 2 | 1.4410 | .0009 | .063 | |
| 1 | 2.6060 | .0020 | .076 | |
| 6 | 3.7493 | .0010 | .027 | |
| 4 | 4.9003 | .0028 | .056 | |
| 1 | 42.0750 | .0340 | .080 | young dogfish |
| 3 | 49.8720 | .0480 | .098 | |
| 2 | 62.3900 | .0660 | .104 | |
| 1 | 72.3500 | .0817 | .112 | |
| 1 | 82.1100 | .1160 | .141 | |
| 1 | 92.7900 | .1030 | .111 | |
| 1 | 102.2950 | .1070 | .104 | |
| 3 | 128.7170 | .3450 | .267 | |
| 4 | 347.1360 | 1.3090 | .378 | |
| 1 | 1498.8000 | 2.7780 | .185 | |

In the dogfish embryo the spleen is relatively small, the maximum in the series observed being .076 % of the total body in an embryo weighing 2.6 grams. With a body weight of .3109 gram, the relative weight of the spleen is .052 %. This steadily increases to the above mentioned maximum and then falls to .027 % for a body weight of 3.7 grams, the minimum percentage observed in the embryos. Then it rises again to .056 % of a body weight of 4.9 grams.

At about birth the percentage weight of the spleen is .098 %, some what lower than that observed by Kellicott (.126 %). This increases rapidly with some fluctuations to .378 % at 347 grams body weight and then falls more

gradually to .185 % in a fish weighing 1499 grams. The variability of the spleen is striking. In two given individuals of approximately the same body weight the spleen of one may be twice or three times as large as the other. This is in agreement with the great variability of the spleen in higher forms.

In the human, Jackson has found the spleen to increase slowly in relative size up to the seventh month; thereafter it increases rapidly, averaging .43 % in the liveborn. Vierordt gives .25 % for the spleen in the adult human. Lowrey finds the prenatal growth curve of the spleen in the pig similar to that of the human. In the white rat, Jackson finds the relative weight at birth to be .22 %, increasing to a maximum of .41 % at one week and thereafter decreasing to .396 % at one year. Welcker and Brandt give data on the relative weight of the spleen with ranges as follows: of fishes, .15 % to .34 %; amphibia, .05 % to .28 %; reptiles, .04 % to .11 %.

h. Rectal Gland

(see next page for table)

The rectal gland, like most of the organs, is relatively heavier in the embryo than after birth. The maximum relative size of the rectal gland (.164 %) occurs in the earliest stage observed, in which the body weight was .0608 gram. This percentage drops with fluctuations to .045 % in an embryo weighing 2.6 grams. At 4.9 grams

RELATIVE GROWTH OF THE RECTAL GLAND
table thirteen

| No. of specimens | Av. net body weight | Av. net wt. rectal gland | Av. rel. wt. rectal gland | |
|---|---|---|---|---|
| 1 | .0608 g. | .0001 g. | .164 | dogfish embryos |
| 5 | .3360 | .0003 | .118 | |
| 3 | .6993 | .0008 | .126 | |
| 2 | 1.4410 | .0011 | .085 | |
| 1 | 2.6060 | .0012 | .045 | |
| 6 | 3.7493 | .0035 | .101 | |
| 5 | 4.9722 | .0046 | .094 | |
| 1 | 42.0750 | .0150 | .035 | young dogfish |
| 3 | 49.8720 | .0260 | .051 | |
| 2 | 62.3900 | .0200 | .032 | |
| 1 | 72.3500 | .0097 | .013 | |
| 1 | 92.7900 | .0430 | .046 | |
| 1 | 102.2950 | .0360 | .035 | |
| 5 | 128.7170 | .0540 | .041 | |
| 3 | 352.3440 | .1410 | .039 | |
| 1 | 1498.8000 | .3410 | .022 | |

body weight, the relative weight of the rectal gland has increased to .094 %.

At about birth the relative size of the rectal gland has diminished to .032 % of the total body weight. Kellicott's figures place this a trifle higher, .0398 %. The rectal gland appears to increase slightly in relative size after birth, reaching .046 % in a fish weighing 92 grams, and thereafter decreasing gradually to .022 % in a fish weighing 1499 grams. Kellicott finds no such increase after birth, the curve of percentage weight falling thruout life.

i. Mesonephros

(see next page for table)

RELATIVE GROWTH OF MESONEPHROS
table fourteen

| No. of specimens | Av. net body weight | Av. net wt. mesonephros | Av. rel. wt. mesonephros | |
|---|---|---|---|---|
| 2 | .0526 grams | .0008 grams | 1.58 | dogfish embryos |
| 6 | .3109 | .0072 | 2.27 | |
| 3 | .6993 | .0217 | 2.99 | |
| 2 | 1.4410 | .0594 | 4.24 | |
| 1 | 2.6060 | .0912 | 3.50 | |
| 6 | 3.7493 | .1317 | 3.50 | |
| 5 | 4.9722 | .1898 | 3.83 | |
| 1 | 42.0750 | .4470 | 1.06 | young dogfish |
| 3 | 49.8720 | .6350 | 1.28 | |
| 2 | 62.3900 | .7870 | 1.25 | |
| 1 | 72.3500 | .5597 | .77 | |
| 1 | 82.1100 | .7140 | .87 | |
| 1 | 92.7900 | .8880 | .96 | |
| 1 | 102.2950 | .9960 | .97 | |
| 3 | 128.7170 | 1.0880 | .84 | |
| 4 | 347.1360 | 2.6780 | .77 | |
| 1 | 1498.8000 | 5.6610 | .38 | |
| 6 | .0290 | .0002 | .93 | Amiurus |
| 2 | .1206 | .0018 | 1.48 | |
| 2 | .2502 | .0036 | 1.54 | |
| 3 | .3548 | .0075 | 2.12 | |

In the dogfish embryo the mesonephros increases from a percentage of 1.5 % at .0526 gram body weight, to a maximum (for the series observed) of 4.24 % at 1.44 grams body weight. At 4.9 grams body weight the relative weight of the mesonephros is 3.83 %.

At about birth the mesonephros forms 1.1 % of the total body weight. This decreases slowly thruout the series observed and probably thruout life. In a fish 1499 grams the percentage weight of the mesonephros is .38 %.

In Amiurus the mesonephros forms .93 % of the total

body weight in six fish with an average body weight of .029 gram. This steadily increases thruout the series, and at .3548 gram body weight has reached a maximum of 2.12 %.

In the human embryo the mesonephros forms only 0.6 % of the body at 11 mm., rapidly decreasing thereafter and practically disappearing at about 30 mm. (Jackson) Lewrey finds the mesonephros of the pig relatively much larger, reaching a maximum relative size of 12 % of the body in the early embryo (15 mm.), decreasing thereafter and practically disappearing at about 125 mm.

j. Gonads.

1. female

RELATIVE GROWTH OF THE OVARIES
table fifteen

| No. of specimens | Av. net body weight | Av. net wt. ovary | Av. rel. wt. ovary | |
|---|---|---|---|---|
| 1 | .4120 g. | .0002 g. | .048 | dogfish embryos |
| 1 | 2.6060 | .0017 | .065 | |
| 4 | 3.6997 | .0020 | .054 | |
| 4 | 4.7724 | .0028 | .057 | |
| 1 | 47.5440 | .2010 | .422 | young dogfish |
| 2 | 62.3900 | .2350 | .374 | |
| 1 | 92.7900 | .2940 | .316 | |
| 2 | 345.9920 | 2.8270 | .814 | |
| 1 | 1498.8000 | 4.2280 | .282 | |

In the embryonic dogfish the ovaries are relatively small. In an embryo weighing .412 gram the percentage weight of the ovaries is .048 %. This increases to a maximum of .065 % in an embryo weighing 2.606 grams. At

4.7 grams body weight the percentage is .057 %.

In the young dogfish the ovaries are relatively much heavier than in the embryo. At about birth the relative weight of the ovaries is .4 %. At 345 grams body weight this percentage has increased to a maximum of .81 %. At 1499 grams body weight the percentage is .28 %. None of the ovaries examined contained large yolk filled ova.

2. male

RELATIVE GROWTH OF THE TESTES
table sixteen

| No. of specimens | Av. net body weight | Av. net wt. testes | Av. rel. wt. testes | |
|---|---|---|---|---|
| 2 | .3347 g. | .0002 g. | .056 | dogfish embryos |
| 3 | .6993 | .0004 | .062 | |
| 2 | 1.4415 | .0008 | .051 | |
| 2 | 3.8480 | .0025 | .066 | |
| 1 | 4.7718 | .0024 | .050 | |
| 1 | 42.0750 | .1510 | .358 | young dogfish |
| 2 | 51.0390 | .1760 | .349 | |
| 1 | 72.3500 | .3627 | .501 | |
| 1 | 82.1100 | .2340 | .284 | |
| 1 | 102.2950 | .5240 | .512 | |
| 3 | 128.7170 | .8620 | .991 | |
| 2 | 348.2810 | 2.3330 | .668 | |

In the dogfish embryo the testes are relatively of about the same weight as the ovaries. The maximum (.066 %) occurs at 3.8 grams body weight and the minimum (.05 %) at 4.7 grams.

In the young dogfish the testes are relatively heavier at birth than the ovaries, the testes forming .402 % of the total body weight. This percentage drops and then sudden-

ly increases to a maximum (for the series) of .99 % at 128 grams body weight. At 348 grams the percentage is .67 %.

Kellicott finds the relative weight of the ovaries of the dogfish to rise after birth to a primary maximum of .675 % in fish of 400 grams. This percentage decreases to .43 % in fish of about 1700 grams and thereafter tends to rise to a second maximum. In the male he finds the testes to rise from .358 % at birth to a primary maximum of .775 % at about 400 grams. This percentage decreases to .60 % at 900 grams and then rises thruout life to a final maximum ratio of 1.15 %. In the human, Jackson finds the sexual gland relatively larger in the embryo than in the later fetal stages and the testis much larger than the ovary at corresponding stages. Vierordt gives the testis and ovary of the newborn as .026 %; for the adult he gives .080 % for the testis and .012 % for the ovary. In the albino rat, Jackson finds the percentage weight of the testes (including epididymis) to increase from an average of .13 % at birth to a maximum of 1.50 % at ten weeks, thereafter decreasing somewhat. In the female he finds the ovaries to increase in relative size from .017 % at birth to .030 % at 10 to 15 grams, thereafter decreasing to .015 % at 60 grams; then the percentage rises to a second maximum of .037 % at 110 to 120 grams and then steadily

decreases. Welcker and Brandt give the following data on the percentage weight of the sex gland: of fishes, .28 % to 8.2 %; amphibia, .26 % to 2.63 %; reptiles, .71 % to 4.00 %.

k. Stomach-Intestines

The following data refer to the empty stomach and intestine.

RELATIVE GROWTH OF THE STOMACH-INTESTINES
table seventeen

| No. of specimens | Av. net body weight | Av. net wt. stomach-int. | Av. rel. wt. stomach-int. | |
|---|---|---|---|---|
| 3 | .0854 g. | .0026 g. | 2.9 | dogfish embryos |
| 5 | .3360 | .0064 | 1.9 | |
| 3 | .6993 | .0134 | 1.9 | |
| 2 | 1.4410 | .0343 | 2.4 | |
| 1 | 2.6060 | .0562 | 2.2 | |
| 6 | 3.7493 | .0975 | 2.5 | |
| 5 | 4.9722 | .1416 | 2.9 | |
| 1 | 42.0750 | 1.4680 | 3.5 | young dogfish |
| 3 | 49.8720 | 1.7060 | 3.4 | |
| 2 | 62.3900 | 1.2560 | 2.0 | |
| 1 | 72.3500 | 2.0340 | 2.8 | |
| 1 | 82.1100 | 2.1900 | 2.7 | |
| 1 | 92.7900 | 2.6210 | 2.8 | |
| 1 | 102.2950 | 2.9900 | 2.9 | |
| 3 | 128.7170 | 5.1060 | 4.0 | |
| 4 | 347.1360 | 16.3670 | 4.7 | |
| 1 | 1498.8000 | 43.8000 | 2.3 | |
| 7 | .0276 | .0022 | 8.5 | Amiurus |
| 2 | .1206 | .0088 | 7.2 | |
| 2 | .2502 | .0171 | 7.2 | |
| 3 | .3609 | .0308 | 8.5 | |

In the dogfish embryo of .0854 gram, the stomach and intestines form 2.9 % of the total body weight. This percentage drops suddenly to 1.9 % at .3360 gram body weight

and thereafter rises thruout the series, being 2.9 % at 4.9 grams body weight.

At about birth the percentage weight of the stomach and intestines is 2.9 %. After birth this percentage increases, reaching a maximum of 4.7 % at 347 grams body weight and thereafter decreasing probably thruout life, being 2.3 % at 1499 grams. This postnatal rise is probably directly due to the change from the embryonic to the free living condition, -- the demand on the digestive system for the digestion and assimilation of an entirely different diet.

In Amiurus with a body weight of .0276 gram, the percentage weight of the stomach-intestines is 8.5 %. At .2502 gram it is 7.2 %. At .3609 gram it rises again to 8.5 %.

In the human embryo, Jackson finds the stomach and intestines variable. In the newborn, Vierordt estimates that the empty stomach and intestines form 2.1 % of the total body weight, and in the adult, 2.06 %. In the albino rat, Jackson finds the percentage weight of the empty stomach and intestines in the newborn to be 2.4 %, increasing to a maximum of 8 % at six weeks and decreasing thereafter to 5 % at 1 year. In the pig, Lowrey finds the percentage weight of the stomach and intestines to increase thruout the prenatal period, being(empty)

about 3.6 % at about full term. In the adult they increase to 4.79 % empty. Welcker and Brandt give data on the percentage weight of the intestinal tract showing ranges as follows: of fishes, 2.31 % to 5.15 %; amphibia, 4.32 % to 6.05 %; reptiles, 4.84 % to 5.68 %.

SUMMARY

1. The head attains a maximum relative size of 38.9 % in the dogfish embryo at .085 gram body weight. At birth this has decreased to about 17.5 % and continues to fall thereafter, probably thruout life. At 1500 grams body weight, it has dropped to nearly 12 %.

2. In general the skin rises thru embryonic life to about 11.5 % at birth and to a slightly higher maximum shortly after birth; thereafter it decreases in relative weight.

3. At birth the relative weight of the skeleton has risen to about 8.7 %. The maximum (9.4 %) occurs shortly after birth, and thereafter the relative weight of the skeleton decreases somewhat.

4. The curve of the relative growth of the musculature and skeleton of the embryo is variable and uncertain. At birth the relative weight of the musculature alone is about 44 % of the total body; this decreases shortly after birth and thereafter increases to nearly 63 % at a body weight of 1500 grams.

5. In the embryo the viscera decrease in relative size from over 19 % of the body at an early period to about 12 % at birth. After birth the percentage weight of the viscera attains a maximum of 14.3 % at about 350 grams body weight and thereafter decreases to 9.8 % at about 1500 grams. The high figures for the early embryos are due chiefly to the relatively large size of the brain.

6. The relative size of the embryonic brain decreases from over 15 % in the early embryo at first rapidly and then more slowly to about 1.6 % at birth. After birth the relative weight of the brain decreases more slowly, but continues to fall thruout the series and probably thruout life.

7. The spinal cord decreases in relative size in the embryo much like the brain, but it is more variable (probably due to error from difficulty in dissection); in the early embryo it forms 1.7 %. At about birth the percentage weight of the spinal cord is .43 %. This figure slightly increases after birth and thereafter decreases slowly. In the embryo the spinal cord is usually only about one tenth as large as the brain, while in the adult it is about one third as large.

8. The relative weight of the eyeballs of the embryonic dogfish is variable, but in general it decreases

from a maximum of about 9 %. At birth it is about 2.1 % and thereafter it decreases slowly. At 1500 grams body weight, the eyeballs form about .64 % of the body, being as large as the brain and spinal cord combined.

9. In general the heart of the dogfish embryo decreases in relative size from a maximum of over 4 %, at first rapidly and then more slowly. At birth it is about .15 % of the total body weight. After birth it rises to nearly .20 % and then decreases again. The figure (.20 %) at about 1500 grams is probably too high, since Kellicott in a large series finds it much lower.

10. The embryonic pancreas remains at about the same relative size for the stages examined, possibly decreasing slightly. At about birth it forms .067 % of the body weight, increasing thereafter to a maximum of .14 % at about 350 grams.

11. In the early embryo the liver rises to a maximum of 5.8 % of the body at .31 gram body weight. This percentage falls gradually and then rises to about 4.8 % at birth. Shortly after birth the liver rises and thereafter decreases in relative weight to about 5.9 % at 1500 grams.

12. In the embryo the spleen is variable but in general it increases in relative weight. At birth the relative weight of the spleen is about .098 % of the total body. This figure increases to a maximum of .38 % at

about 350 grams and thereafter decreases. The spleen is exceedingly variable in weight.

13. The relative weight of the rectal gland is rather variable in the embryo, but falls from a maximum of .164 % to about .032 % at birth. Shortly after birth the relative weight increases slightly and thereafter decreases.

14. The relative weight of the embryonic mesonephros increases to a maximum of 4.2 % at 1.44 grams body weight, and then decreases. At birth it has fallen to about 1.1 % and continues to decrease thereafter.

15. The testes and ovaries of the embryo are relatively of about the same weight, the testes being slightly heavier. At birth the relative weights of the testes and ovaries are about .40 % of the body. The testes increase to a maximum of 1.0 % at about 130 grams. The maximum for the ovaries (.81 %) occurs at about 350 grams and the relative weight thereafter falls to .28 % at about 1500 grams.

16. The percentage weight of the stomach and intestines on the whole increases in the embryo from a minimum of 1.7 % at .31 gram to about 2.9 % at birth. After birth the stomach and intestines increase to a maximum of 4.7 % at about 350 grams and thereafter decrease, probably thruout life.

17. Although many minor differences may be observed,

on the whole the course of the relative growth of the various organs and parts in the dogfish is strikingly similar to that which has been observed among the higher vertebrates, including mammals and man.

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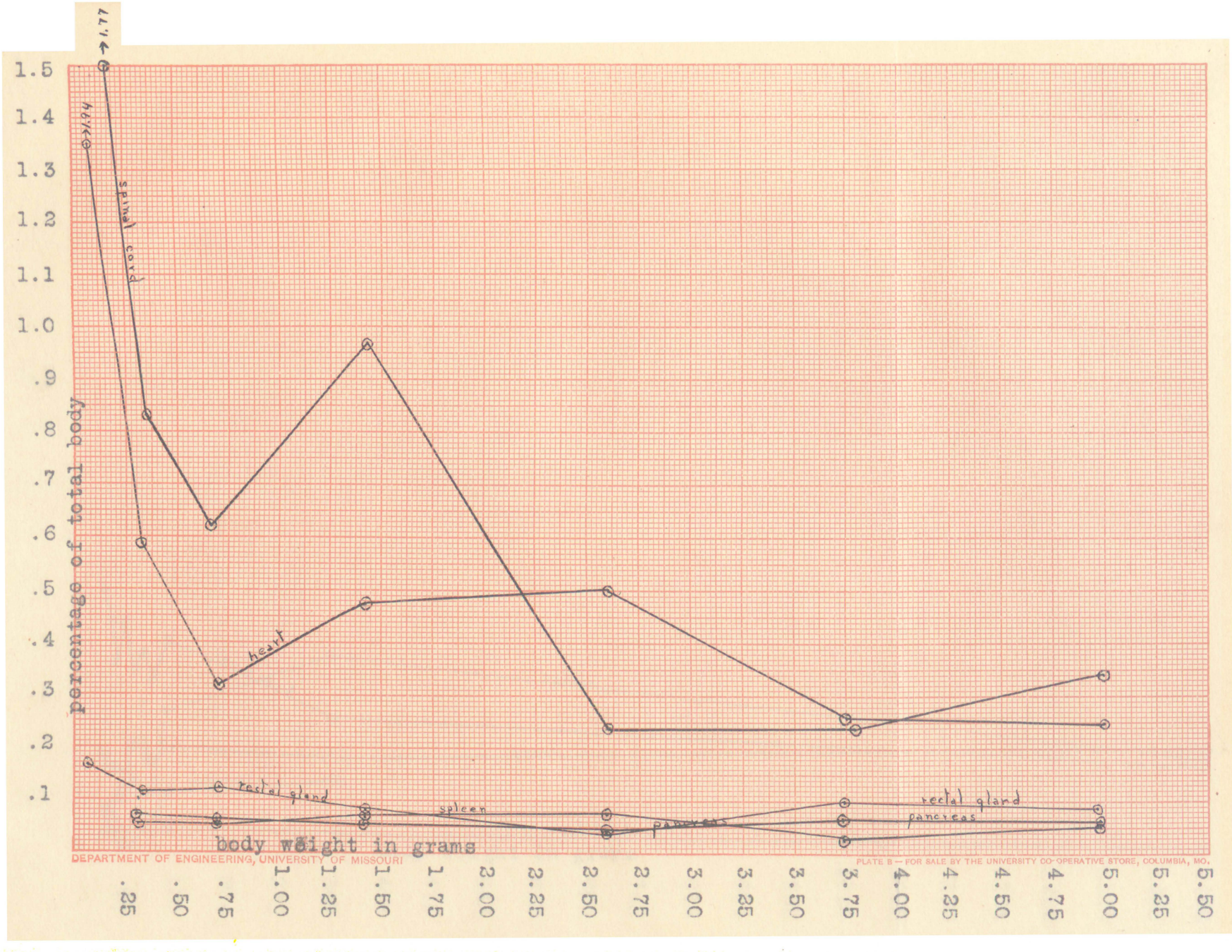
1.77
4.94
spinal cord
heart
rectal gland
spleen
pancreas
rectal gland
pancreas
percentage of total body
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
body weight in grams
.25
.50
.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
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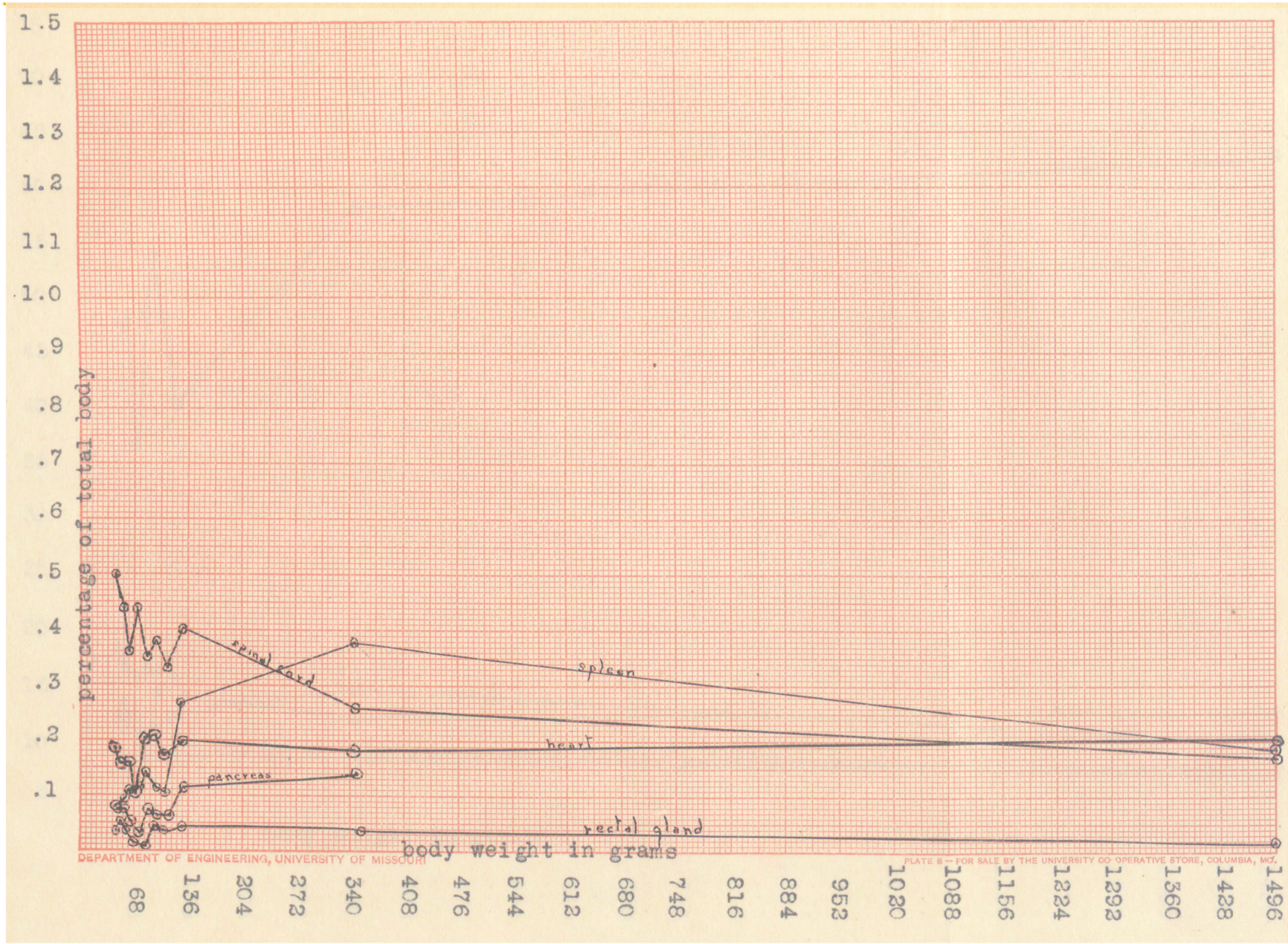
percentage of total body
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
spinal cord
spleen
heart
pancreas
rectal gland
body weight in grams
68
136
204
272
340
408
476
544
612
680
748
816
884
952
1020
1088
1156
1224
1292
1360
1428
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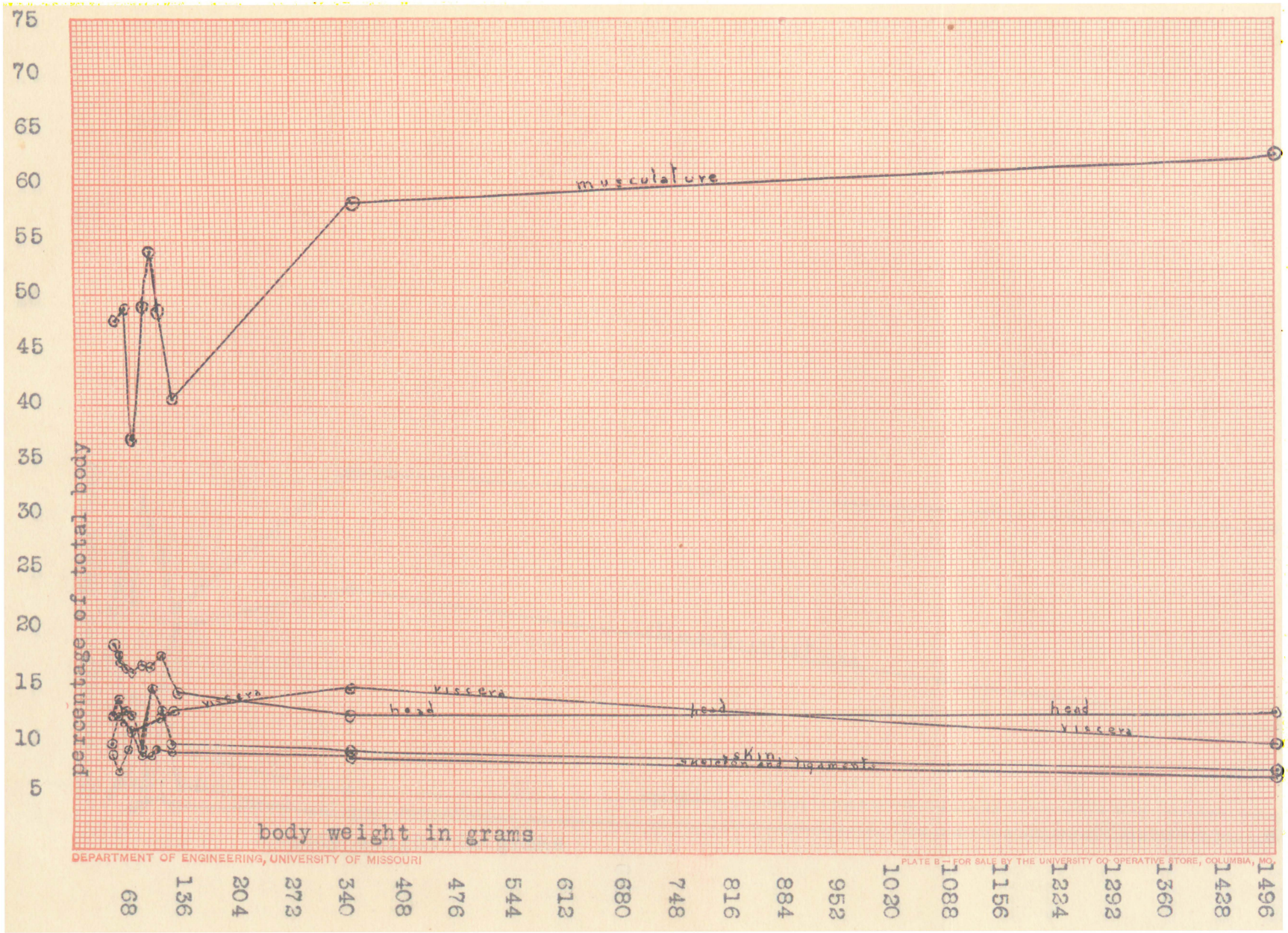
percentage of total body
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
musculature
viscera
head
viscera
head
head
viscera
skin
skeleton and ligaments
body weight in grams
68
136
204
273
340
408
476
544
612
680
748
816
884
952
1020
1088
1156
1224
1292
1360
1428
1496
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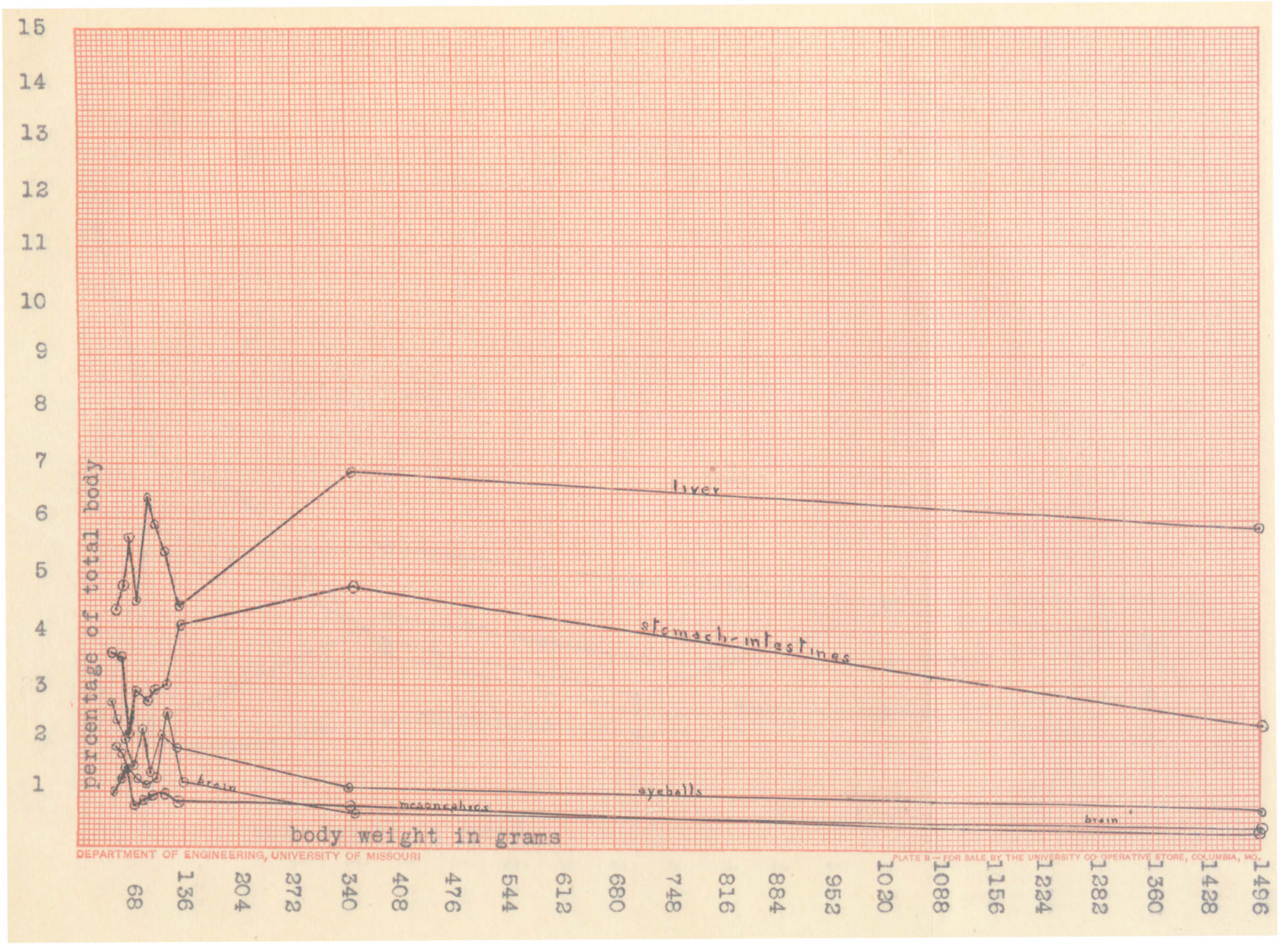

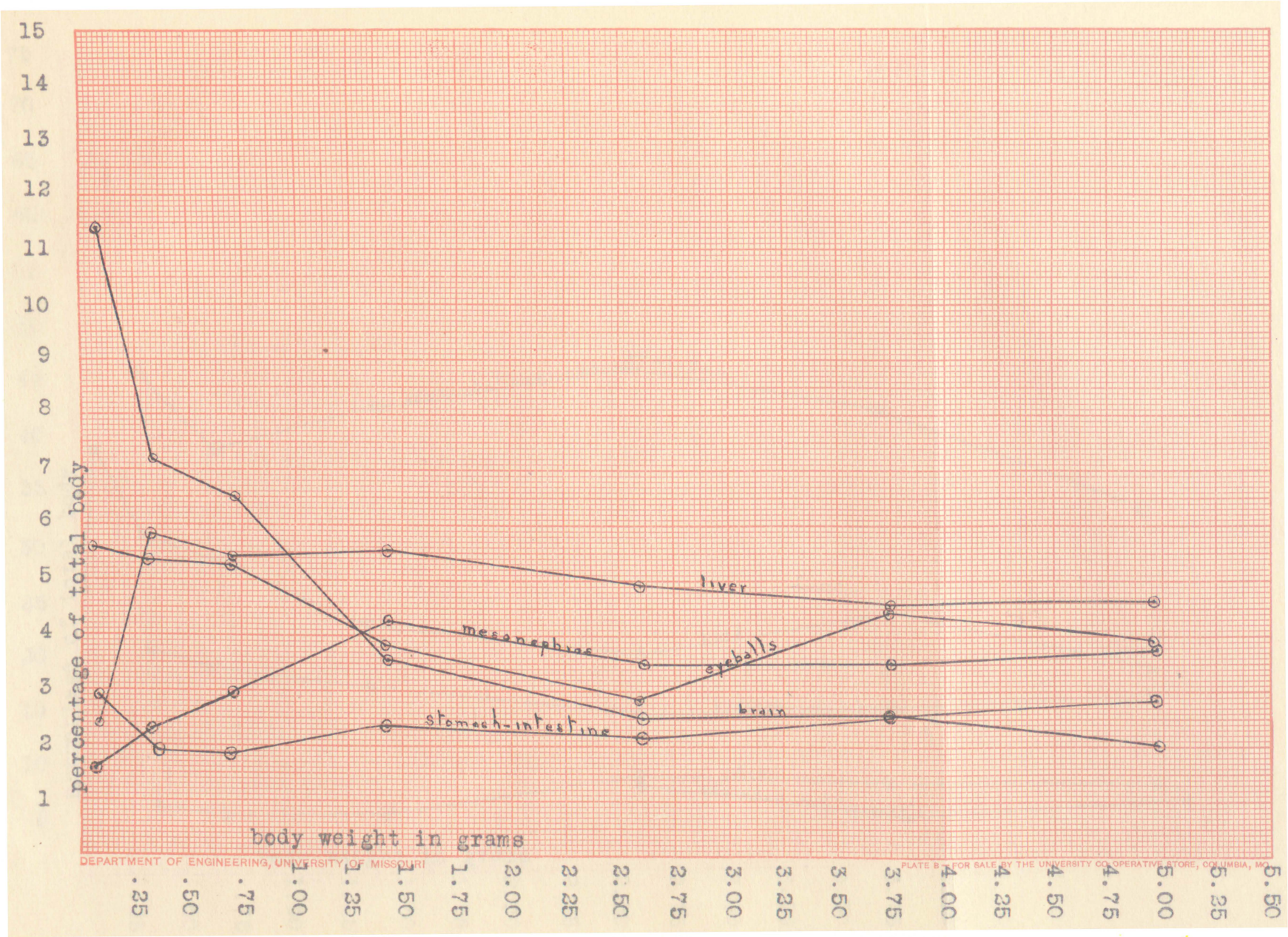
percentage of total body
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
liver
mesonephros
eyeballs
brain
stomach-intestine
body weight in grams
.25
.50
.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
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percentage of total body
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
musculature and skeleton
head
viscera
skin
skeleton and ligaments
body weight in grams
.25
.50
.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
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