THE DEGREE OF COMPENSATORY RENAL HYPERTROPHY FOLLOWING UNILATERAL NEPHRECTOMY

II. THE INFLUENCE OF THE PROTEIN INTAKE*

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The ingestion of a diet containing more than the usual amount of protein is followed by a remarkable increase in the weight of the kidneys (1-8). This investigation was designed to determine the influence of similar variations in the protein intake upon the degree of compensatory renal hypertrophy following unilateral nephrectomy.

Since the appearance of our first preliminary note on this subject (4) there have been two papers (9, 10) dealing with the influence of the protein intake upon compensatory renal hypertrophy in which the conclusions are quantitatively very much at variance with the data presented here. Since the difference between the results of Smith and Moise (9) and Allen and Mann (10) and our own are due to their method of expressing results, it would seem desirable to obviate further confusion by defining more exactly what is meant by compensatory hypertrophy and to describe our method of measurement.

When, as in our experiments, one kidney is removed, the remaining kidney grows larger and it is this enlargement which is called compensatory hypertrophy. Compensatory hypertrophy is expressed as the percentage increase of the hypertrophied kidney over the probable weight of the same kidney at that time had the animal had two kid-

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1 These investigators failed to include a control group treated in the same manner as their nephrectomized animals, so they were not actually measuring compensatory hypertrophy but rather the sum of the hypertrophy due to the increased protein intake plus the compensatory hypertrophy.
### TABLE I

| Experiment | Operation | Days | Deaths | Protein in diet | Number of rats | Initial | Body weight | Group at death | Corrected | Body surface | Kidney weight | Protein intake* | Number of rats | Initial | Body weight | Group at death | Corrected | Body surface | Kidney weight | Protein intake* | Control group | Nephrectomy group | Kidney per 100 sq. cm. body surface | Difference | Compensatory renal hypertrophy |
|------------|-----------|------|--------|----------------|----------------|---------|-------------|----------------|-----------|--------------|---------------|----------------|----------------|---------|-------------|----------------|-----------|--------------|---------------|----------------|---------------|-------------------|---------------|------------------------|
| 1          | 30        | 70   | 12     | 18             | 40 169 163    | 138 633 0.45 | 17          | 31 161 154 | 325 896 0.47 | 187 261 74 | 39.6         | 185 266 81 | 43.8    | 185 266 81 | 43.8          |           |              |               |               |               |                   |               |                        |
| 2          | 30        | 70   | 18     | 25             | 42 179 170    | 347 644 0.61 | 26          | 42 173 164 | 340 903 0.59 | 185 266 81 | 43.8         | 185 266 81 | 43.8    | 185 266 81 | 43.8          |           |              |               |               |               |                   |               |                        |
| 3          | 30        | 70   | 31     | 18             | 47 216 212    | 403 835 0.95 | 17          | 51 220 216 | 404 1289 0.90 | 207 310 103 | 49.7         | 207 310 103 | 49.7    | 207 310 103 | 49.7          |           |              |               |               |               |                   |               |                        |
| 4          | 30        | 70   | 43     | 21             | 42 197 195    | 381 832 1.30 | 19          | 41 189 186 | 369 1235 1.40 | 221 335 114 | 51.6         | 221 335 114 | 51.6    | 221 335 114 | 51.6          |           |              |               |               |               |                   |               |                        |
| 5          | 30        | 70   | 67     | 29             | 39 167 159    | 332 964 2.49 | 29          | 40 157 149 | 318 1398 2.61 | 286 439 153 | 53.5         | 286 439 153 | 53.5    | 286 439 153 | 53.5          |           |              |               |               |               |                   |               |                        |
| 6          | 360       | 400  | 12     | 14             | 375 416 404   | 616 1024 0.19 | 11          | 356 391 385 | 654 1247 0.19 | 166 300 34  | 20.3        | 166 300 34  | 20.3    | 166 300 34  | 20.3          |           |              |               |               |               |                   |               |                        |
| 7          | 360       | 400  | 18     | 22             | 318 372 367   | 581 1035 0.38 | 19          | 325 365 360 | 573 1255 0.39 | 178 219 41   | 23.1        | 178 219 41   | 23.1    | 178 219 41   | 23.1          |           |              |               |               |               |                   |               |                        |
| 8          | 360       | 400  | 31     | 13             | 366 414 410   | 627 1102 0.56 | 14          | 354 382 378 | 593 1436 0.54 | 179 243 64   | 35.7        | 179 243 64   | 35.7    | 179 243 64   | 35.7          |           |              |               |               |               |                   |               |                        |
| 9          | 360       | 400  | 67     | 26             | 315 317 312   | 521 1145 1.34 | 27          | 325 306 308 | 516 1580 1.27 | 219 307 88   | 40.2        | 219 307 88   | 40.2    | 219 307 88   | 40.2          |           |              |               |               |               |                   |               |                        |

* Grams per 100 sq. cm. body surface per day. The average of the last 10 days of each experiment.
neys and been under identical conditions of environment, diet, and experimental variables of other kinds. Since it is impossible to weigh the kidney before and during the enlargement it is assumed that one kidney of a similar control animal equals the weight of the remaining kidney, had no compensatory hypertrophy occurred. Since control

![Graph](image)

FIG. 1

and experimental animals of quite identical size cannot be obtained the actual comparison is made between the kidney weights per 100 sq. cm. of body surface (11). The degree of compensatory hypertrophy is measured 40 days after unilateral nephrectomy since after that time there is no further enlargement under our conditions (12).
The technical methods which were used have been detailed elsewhere (11, 12, 13). Diets containing 12.4, 18.0, 31.2, 42.9, and 67.2 per cent protein mostly as casein were used. The protein represented 10.5, 15.7, 27.3, 39.8, and 70.0 per cent of the calories respectively. These diets have already been described (8).

Our results have been summarized in Table I. In Fig. 1 the averages have been plotted and curves drawn to indicate the general relation between the protein intake and the degree of compensatory renal hypertrophy in these experiments. The lines in Fig. 2 suggest the relationship between the hypertrophied kidney weight and the protein intake at the two ages.

From the data presented here a number of conclusions, governed by the conditions of our experiments, may be drawn. These are as follows:

1. In young rats and old rats an increase in the protein intake results in an increase in the degree of compensatory hypertrophy, which is of greater magnitude (Table I and Fig. 1) in old rats.

2. In young rats and old rats as the protein intake is successively increased above a minimum level the increment of increase in the degree of compensatory renal hypertrophy becomes less and less (Fig. 1). This decrease is more noticeable in young rats than in old rats but at both ages is particularly noticeable when the protein intake surpasses that which we have termed optimal (7) because it gave the
best body growth. Arithmetically this decrease is inevitable because the kidney weights of both two kidney rats (8) and rats with an hypertrophied kidney (Fig. 2) bear very nearly linear relationships to the protein intake.

3. The protein intake has the same influence upon the kidney weight of rats with two kidneys at all ages (8) and the hypertrophic kidney is increased in weight the same absolute amount by a given increase in the protein intake in both old and young rats (Fig. 2). However, both at a zero protein intake or any given positive protein intake the hypertrophic kidney is larger the younger the organism. This results in the conclusion recorded in the first paper of this series (12) that compensatory hypertrophy of the kidney becomes less as age advances.

SUMMARY

Compensatory hypertrophy of the kidney in albino rats is increased by an increase in the protein intake. The effect is greater in old rats than young rats. Successive increases in the protein intake are followed by a reduction in the increase in the degree of compensatory renal hypertrophy.

BIBLIOGRAPHY