Deoxyribonucleic acid and ribonucleic acid content of human tissues obtained at necropsy

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SYNOPSIS Values for the deoxyribonucleic acid and ribonucleic acid contents in a considerable number of human post-mortem tissues are given and briefly discussed.

The deoxyribonucleic acid (D.N.A.) content of a tissue sample is, with certain reservations, a reasonable measure of the number of cells in that sample. This follows from the almost constant D.N.A. content per nucleus (Vendrely, 1955) in many types of cells in somatic tissues. Deviations from this role only occur, for instance, in cells displaying polyploidy or in multinucleate varieties, and in a few other reported instances (Vendrely, 1955). Thus, measurement of D.N.A. affords a simple means of determining the numbers of cells in samples of tissue particularly where, because of large quantities of extracellular material, *e.g.*, milk in samples of mammary gland (Greenbaum and Slater, 1957a), other estimations, such as total protein, bear little relation to the cellular content (Davidson and Leslie, 1950). Measurements of ribonucleic acid (R.N.A.) do not have the same applicability but, as an approximation, the R.N.A. content of a tissue reflects the rate of protein synthesis proceeding in that tissue. For instance, the R.N.A. content of tissues such as liver, lactating mammary gland, and pancreas is much higher than that, say, of skeletal muscle or skin (see Table III).

It was suggested to us by Dr. E. Pochin, Director of the Department of Clinical Research at this Medical School, that it would be of interest to measure the D.N.A. content per gram wet weight of a large number of human tissues. Such values, which, to our knowledge, have not previously been reported, would be proportional in the first approximation to the cell numbers per gram wet weight. The estimated number of cells per organ, *i.e.*, the D.N.A. content per organ, might prove of relevance to the likelihood of late changes developing after irradiation of different organs. In an attempt to provide at least limited data in this respect we have estimated D.N.A.

(and R.N.A.) in 20 different types of human tissue obtained after death.

Although only a few cases have been used in this study, due to the problem of obtaining suitable material, it is believed that the data presented will enable a reasonable comparison to be made between the D.N.A. and R.N.A. content of a considerable number of human tissues. This belief is strengthened by the fact that estimations have been carried out on as many as 18 tissues from the same case.

METHODS

Tissue samples (obtained at necropsy) were obtained from cases where the cause of death had involved no infection or long-standing chronic illness. The samples (approximately 1 g.) were placed in bottles containing ice-cold water for transport to the laboratory and all subsequent procedures were carried out as quickly as possible. The cold tissue samples were rapidly weighed and then homogenized in approximately 5 ml. cold water using a Turrax type homogenizer. Each tissue suspension was then transferred to stoppered centrifuging tubes and mixed with an equal volume of cold 10% trichloroacetic acid. After standing in ice for 20 min. the pellet was centrifuged down and washed twice with approximately 5 ml. cold 5% trichloroacetic acid. The pellet was then suspended in 8 ml. 5% trichloroacetic acid and warmed at 90°C. for 20 min. to extract the nucleic acids into solution (Schneider, 1945). After cooling, the protein residue was centrifuged down and rejected. The supernatant was filtered and used for the estimation of D.N.A. and R.N.A. Deoxyribonucleic acid was estimated by the method of Burton (1956) using suitable volumes of the supernatants (0.2 to 1.0 ml.) such that the final extinction at 600 m μ was in an accurate region of the spectrophotometer. Ribonucleic acid was measured in the 5% trichloroacetic acid extracts by the orcinol procedure (Greenbaum and Slater, 1957b).

The results for both D.N.A. and R.N.A. are expressed in terms of phosphorus content (D.N.A.P., R.N.A.P.) as is the normal practice; values given for rat tissues in

TABLE I

D.N.A.P. CONTENTS OF HUMAN POST-MORTEM AND RAT TISSUES¹

Tissue	Human				Rat		
	Male				Female		
	Case A (Age 71)	Case B (Age 70)	Case C (Age 60)	Mean	Case D (Age 18)	Case E (Age 71)	Mean
Liver	12.9	7.7	—	10.3	—	9.9	—
Kidney	11.8	11.9	—	11.8	—	10.7	—
Spleen	22.7	38.3	—	30.5	—	33.1	—
Brain	3.1	1.2	—	2.2	—	2.0	—
Adrenal	8.9	3.5	—	6.2	—	6.6	—
Pancreas	24.2	12.9	17.6	18.2	22.6	13.0	17.8
Thyroid	16.3	5.8	9.4	10.5	11.8	6.3	9.0
Ovary	—	—	—	—	25.3	—	—
Prostate	—	7.7	8.6	8.1	—	—	—
Testis	—	13.5	17.0	15.3	—	—	—
Uterus	—	—	—	—	—	—	—
Lung	14.3	9.2	—	11.7	—	8.4	—
Adipose	0.6	1.0	—	0.8	0.5	.7	0.6
Red marrow	10.1	10.9	—	10.5	—	13.8	—
Skin	1.1	2.4	3.4	2.3	3.7	—	—
Small intestine	19.1	17.9	15.0	17.3	11.4	—	—
Large intestine	6.4	9.4	6.9	7.6	4.9	—	—
Stomach wall	11.0	11.1	—	11.0	22.5	7.5	—
Lymph node	42.1	30.3	32.7	35.1	54.5	27.2	—
Skeletal muscle	1.8	1.8	2.2	1.9	2.0	1.9	2.0

¹Values are given as mg./100g. wet wt. tissue.

Table I for comparison were obtained by identical procedures to those outlined for the human post-mortem samples.

RESULTS

Table I shows the results obtained for the D.N.A.P. content of a variety of human and rat tissues. It can be seen that on a mg./100 g. wet weight basis the human samples fall roughly into three groups: 1 D.N.A.P. content high (over 25 mg./100 g. wet wt.) in spleen, lymph node, ovary; 2 D.N.A.P. content medium (10-20 mg./100 g. wet wt.) in liver, kidney, pancreas, thyroid, testis, lung, red marrow, small intestine, stomach wall; 3 D.N.A.P. content low (less than 8 mg./100 g. wet wt.) in brain, adrenal, prostate, adipose, skin, large intestine, and skeletal muscle. The range covered by the values in the various tissues examined is large, the difference being 40-fold between the mean values for male adipose tissue and lymph node. Values obtained for the rat show little comparison with the human results. The rat D.N.A.P. content is in every case higher, and sometimes, much higher, than the corresponding human tissue. Using mean weights for each organ (Spector, 1956), the approximate D.N.A.P. content per whole organ can be calculated (Table II). With this method of expressing the results it can be seen that the liver and lungs have much higher D.N.A.P. contents than any of the other tissues examined. Tissues with an intermediate D.N.A.P. content are kidney, spleen, brain, and

TABLE II

D.N.A.P. CONTENT OF VARIOUS HUMAN POST-MORTEM TISSUES¹

Tissue	Mean Weight of Organ	D.N.A.P. (mg./total organ wt.)
Liver	1,838 (a)	186.5
Kidney	313 (a)	36.8
Spleen	204 (a)	62.0
Brain	1,355 (a)	29.8
Adrenal	14 (a)	0.86
Pancreas	85 (b)	15.5
Lung	953 (a)	112.0
Thyroid	25 (a)	2.6
Prostate	17 (a)	1.38
Testis	28 (a)	4.28
Ovary	10 (c)	2.53

¹The D.N.A.P. contents/100 g. wet weight tissue used in this calculation are taken from the mean values in Table I. The weights for different organs were obtained from Spector (1956) for (a) males, 20-30 yr. old, body wt. approximately 71 kg., (b) males, 16-17 yr. old, body wt. 62 kg., and (c) females, 20-30 yr. old, body wt. 56 kg.

perhaps pancreas; the other tissues have a total D.N.A.P. content of less than 3% of the liver value.

Table III shows the results obtained for ribonucleic acid phosphorus content. The results are more variable from case to case than were found for deoxyribonucleic acid phosphorus. This variability could represent the differences in secretory activity of the different tissues since, with one exception, all of the cadavers used were old and presumably some variable degree of atrophy was present.

Although these estimations have been performed on a limited number of cases, and although sampling errors resulting from using relatively small amounts

TABLE III

R.N.A.P. CONTENT OF VARIOUS HUMAN POST-MORTEM AND RAT TISSUES¹

Tissue	Human					Rat
	Male			Female		
	Case A	Case B	Case C	Case D	Case E	
Pancreas	80.0	18.2	58.8	51.7	37.2	139
Thyroid	15.8	9.5	9.2	12.1	8.6	34
Small intestine	16.3	15.0	12.6	13.7	—	—
Large intestine	6.5	9.7	7.0	5.5	—	73
Stomach wall	9.1	18.6	—	24.8	10.3	—
Lymph node	26.3	16.2	18.8	22.5	15.3	—
Skeletal muscle	3.75	4.7	5.2	5.5	3.4	9
Skin	2.1	3.7	5.4	4.8	—	—
Ovary	—	—	—	17.8	—	35
Testis	—	7.2	19.2	—	—	20
Prostate	—	10.0	9.6	—	—	30
Adipose	52	1.02	—	0.99	2.01	—
Liver	31.0	28.3	—	—	41.3	50
Red marrow	6.2	7.6	—	—	11.0	—
Kidney	14.4	15.3	—	—	15.3	—
Spleen	14.4	22.7	—	—	21.5	—
Lung	12.6	6.65	—	—	6.65	39
Adrenal	9.7	6.5	—	—	13.4	—
Brain	6.3	2.7	—	—	5.75	—

¹Values are given as mg./100 g. wet wt. tissue and the method of estimation used was that of Greenbaum and Slater (1957b).

of tissue were undoubtedly present, it is believed that the values in Tables I-III give a reasonably close estimate of the nucleic acid contents of 20 human tissues. As such it is hoped that they may prove of interest.

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REFERENCES

- Burton, K. (1956). *Biochem. J.*, **62**, 315.
 Davidson, J. N., and Leslie, I. (1950). *Nature (Lond.)*, **165**, 49.
 Greenbaum, A. L., and Slater, T. F. (1957a). *Biochem. J.*, **66**, 148.
 —, — (1957b). *Ibid.*, **66**, 155.
 Schneider, W. C. (1945). *J. biol. Chem.*, **161**, 293.
 Spector, W. S. (1956). In *Handbook of Biological Data*, edited by W. S. Spector, p. 162. Saunders, Philadelphia.
 Vendrely, R. (1955). In *The Nucleic Acids*, vol. 2, edited by E. Chargaff and J. N. Davidson, p. 155. Academic Press, New York.