Relationships of Adrenals, Gonads, and Thyroid to Thymus and Lymph Nodes, and to Blood and Thoracic Duct Leukocytes

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The following evidence is presented to demonstrate interrelationships found to exist between the weight of lymphatic tissues (thymus and lymph nodes), and numbers of blood and thoracic duct leukocytes as affected by adrenalectomy, gonadectomy, thyroidectomy, and by thyroxine administration, separately and in combination.

Experimental Methods

Male rats of the Long-Evans strain were separated into three groups, each consisting of 40 animals: (1) normal, (2) thyroxine treated, and (3) thyroidectomized. Each of these groups was further divided into four subgroups: (a) control, (b) gonadectomized, (c) adrenalectomized, and (d) adrenalectomized-gonadectomized.

The rats were maintained on this laboratory's Diet 1,* supplemented with fresh lettuce weekly. All animals were maintained on 1 per cent sodium chloride during the experimental period. Initial experimental procedures were carried out on rats at 50-60 days of age. The animals were then maintained for a period of 40 days, at the end of which time terminal procedures were carried out. Duplicate total leukocyte counts, total direct eosinophil counts, and differential leukocyte counts (100 cells), were determined by tail blood sampling. All blood counts were made at the same hour of the day for each animal to avoid diurnal variations. Initial and terminal body weights were measured. Following the initial blood determinations, operative procedures were performed on each group. Adrenalectomy, gonadectomy, and thyroidectomy were carried out by standard technics under sodium pentobarbitol (intraperitoneal injection of seven mg. per 100 Gm. body weight, in 2 per cent aqueous solution) anesthesia. Control animals were not sham operated.

A buffered solution of L-thyroxine containing 100 gamma L-thyroxine equivalent/ml. was employed. During the 40 day experimental period, the thyroxine-treated groups received daily intraperitoneal injections. Injections were begun at the 5 mg. level, this dose being doubled every five days up to the 30th day of the experiment, at which time the dose level was reduced by one half for the last 10 days of the experiment. Although normal animals were not affected, this reduction was necessary since the adrenalectomized animals did not tolerate the higher dose level. Control animals were injected with the same volume of 0.9 per cent NaCl. The reduced tolerance of the adrenalectomized rats to either hyperthyroidism or hypothyroidism was demonstrated by the fact that approximately 70 per cent of such animals did not survive the experimental period. Physical condition at the end of the experimental period indicated that the thyroxine-treated animals were in a distinctly hyperthyroid state. At autopsy, lymph flow and the number of lymphocytes in the thoracic duct lymph were measured. The thymus, cervical and mesenteric lymph nodes were re-

* Composition of Diet I: whole wheat 67.5 per cent, casein 15 per cent, whole milk powder 10 per cent, iodized NaCl 0.75 per cent, CaCO₃ 1.5 per cent, hydrogenated vegetable oil 5.25 per cent and fish oil concentrate in amount to give 1.5 chick units of vitamin D and 10.5 International Units of vitamin A per Gm. of diet.
moved and weighed according to a technic previously described. Representative tissues were fixed, sectioned and examined histologically. Protein nitrogen (micro-Kjeldahl) was determined on aliquots of the total samples of thoracic duct lymph, and was found to be in proportion to the volume of lymph flow for each group.

In order to determine the relative significance of the observations, differences of absolute and relative mean values* were tested by Fisher's method4 for the distribution of "t". Values of $P < .01$ were considered to be highly significant. Differences of mean values with ($P > .01$) are not designated in the text.

**RESULTS AND DISCUSSION**

Excellent and detailed reviews of the numerous experiments relating to aspects of the relationships of individual hormones to lymphatic tissues have been made available by Valentine, Craddock and Lawrence,6 Yoffey,6 and Dougherty.7 The following discussion is restricted, therefore, to a correlation of the effects of adrenalectomy, gonadectomy, thyroidectomy, and thyroxine treatment, separately or combined, on the weights of the lymphatic tissue, as related to circulating blood and thoracic duct leukocytes. No paired feeding technics or measurements of food or fluid intake were employed in this investigation; all interpretations of responses are, therefore, subject to any alterations which may have occurred in these variables.

*Tables of mean values and standard errors may be obtained on request to the authors.*
the lymph nodes, this difference being augmented by administration of thyroxine. It would appear, however, that gonadal secretions exert but a slight inhibiting influence on the weights of the cervical and mesenteric lymph nodes, whereas a more marked influence is exerted on the thymus.

2. **Effect of adrenalectomy.** Analysis of the results demonstrates that a marked increase occurred in the weights of the thymus, cervical and mesenteric lymph nodes following adrenalectomy in normal and thyroxine-treated animals. This marked increase in the weight of the thymus and lymph nodes after adrenalectomy (see reviews by Valentine, Craddock and Lawrence,\(^4\) and Dougherty\(^5\)) substantiates the reports by Crowe and Wislocki,\(^6\) Banting and Gairns,\(^7\) Marine,\(^8\) Simpson, Dennison and Korenchevsky,\(^9\) Reinhardt and Holmes,\(^10\) Rapela,\(^11\) Mar-der,\(^12\) and Feldman.\(^13\)

![Graphs showing weight comparisons](image)

**FIG. 1.—Weights of lymphatic tissues of 90 day old male rats, 40 days after onset of indicated procedures.**

From the evidence of the present experiments, it is apparent that the controlling influences of gonadal and adrenal secretions on the weight of the thymus are approximately equivalent, since the removal of the gonads resulted in an increase in the weights of the thymus on an absolute and relative basis, which was approximately the same as that produced by removal of the adrenals. When the gonads and adrenals were removed simultaneously, the mean weights of the thymus were significantly increased over the values obtained for removal of either the gonads or adrenals. This is well demonstrated for the thymus, since combined removal of the gonads and adrenals in thyroxine-treated groups doubled the relative weight of the thymus as compared with the relative weights of the thymus in thyroxine-treated gonadectomized or adrenalectomized animals. The inhibiting influence of secretions of the gonads and adrenals on the weights of the lymph nodes appears to differ from their effects on the thymus. Gonadec-
omation seems to remove only a slight inhibiting influence on the weights of the lymph nodes, whereas removal of the adrenal produced a marked increase in weight.

3. Effects of thyroxine administration and of thyroidectomy. The administration of thyroxine did not increase the weight of the thymus in intact animals. It did, however, increase the weights of the cervical and mesenteric lymph nodes when compared with untreated control values. Hoskins\(^3\) administered large doses of fresh thyroid to rats for periods of 10–20 days and reported that the thymus was, on the average, ten per cent lighter than control values. Herring\(^3\) gave small daily doses of fresh thyroid for 40 days to white rats and observed no effect on the weight of the thymus. Cameron and Carmichael\(^1\) reported an increase in the weights of the cervical and axillary lymph nodes after injections of small doses of thyroxine into rats and rabbits. Andreasen\(^3\) found that small doses of thyroid administered to guinea pigs had no effect on the thymus weight, whereas larger doses produced a slight atrophy of the thymus. Marder\(^2\) administered thyroxine to adult mice and studied the effects produced on the thymus and lymph nodes. He found that thyroxine significantly increased the weights of the lymph nodes as compared with control values, whereas the weights of the thymus were slightly smaller than in untreated control animals. Reinhardt and Wainman\(^\) injected thyroxine into male rats for a period of 35 days at a lower total dose level than was administered in the present investigation. They found no change in the weight of the thymus. The cervical and mesenteric lymph nodes were observed to increase in weight; the increase was not statistically significant when compared with the weights of untreated controls. Feldman\(^\) injected a total dose level of thyroxine, approximately equal to that administered in this experiment, into rats over a relatively shorter period and found that the thymus decreased slightly in weight; no change was noted in the absolute and relative weights of the lymph nodes. The results of the above investigations suggest that whereas small quantities of thyroxine may be adequate to increase the weight of the lymph nodes, that the same doses of thyroxine had no effect on the weight of the thymus in normal animals.

From the results presented here, thyroxine treatment combined with adrenalectomy or with adrenalectomy-gonadectomy appears to further augment the increase in the weights of the thymus and lymph nodes, as compared to weights in untreated adrenalectomized or adrenalectomized-gonadectomized animals. This confirms the reports of Reinhardt\(^2\) for rats, and Marder\(^2\) for mice. Thyroidectomy, on the contrary, prevented any increase in the weights of the thymus and lymph nodes, irrespective of whether the adrenals or gonads were removed separately, or in combination, as compared with animals with an intact thyroid or receiving thyroxine treatment. The results obtained in these experiments for the effects of thyroidectomy confirm those reported by Marine, Manley and Baumann\(^1\)\(^0\) for rabbits, Houssay\(^2\) for mice, and Chiodi,\(^1\)\(^6\) Reinhardt and Wainman,\(^1\)\(^8\) Rapela,\(^2\)\(^5\) and Feldman\(^2\)\(^7\) for rats.

The evidence suggests that hypersecretion of the thyroid causes a marked increase in the weights of the thymus in the absence of the adrenals and/or gonads. Support is thus provided for the generalization of Marine, Manley and Baumann,\(^1\)\(^0\) and others,\(^1\)\(^4\) that enlargement of the thymus in instances of hyper-
thyroidism is related to hypogonadism and/or hypoadrenocorticalism. The evidence presented here indicates, moreover, that unlike the response of the thymus, the enlargement of the lymph nodes in hyperthyroidism appears to be related to the intrinsic sensitivity of the lymph nodes to thyroxine, and is exaggerated by associated hypoadrenocorticalism, but not to the same extent by hypogonadism.

Factors Influencing the Circulating Blood Leukocyte and Eosinophil Leukocyte Counts (fig. 2)

1. Effect of gonadectomy. Gonadectomy did not alter the total blood leukocyte, direct eosinophil, or differential leukocyte counts from values recorded for the intact control animals, nor did removal of the gonads significantly alter the change in the blood lymphocytes or eosinophils that occurred following adrenalectomy in otherwise intact animals. These results confirm the reports on the lack of effect of gonadectomy on the blood leukocytes presented by McCullagh and Jones,34 Stein and Jacobsen,35 Crafts,36 McDermott, Fry, Brobeck and Long,37 Simms, Pfeiffenberger and Heinbecker,38 and others.

2. Effect of adrenalectomy. The removal of the adrenals increased the total number of blood leukocytes and eosinophils and also increased the percentage of these latter cells as compared with the initial control counts. In most instances this increase was statistically significant. Since the differential mononuclear counts were not appreciably altered concomitant with an elevation in the total number of blood leukocytes, the increases represented an absolute increment in mononuclear cells. The results presented here corroborate the experimental reports of increased levels of blood lymphocytes, and the few experimental obser-
vations of an eosinophilic leukocytosis following adrenalectomy. Some reports (reviewed by Valentine, Craddock, and Lawrence) have not been confirmatory of investigations showing an increase in lymphocytes in the blood after adrenalectomy. The majority of investigations on the effect of adrenalectomy have been concerned, however, with relatively short intervals following adrenalectomy, or with animals in acute insufficiency. The varying results suggest that mentioned alterations in the blood leukocyte levels may not be observed unless an appreciable length of time has elapsed subsequent to adrenalectomy, and in optimally maintained animals.

3. Effect of thyroxine administration or thyroidectomy. The dose level of thyroxine administered in the present experiments did not alter the total number of blood leukocytes, eosinophils, or differential leukocyte counts when compared to control values. These results confirm the reports on experimental animals by Linn, Sarker and Brown, Latta and Benner, and Simms et al. Thyroxine did not augment the effect of adrenalectomy in increasing the number of blood lymphocytes and eosinophils. This evidence lends weight to the growing consensus (see Simms et al., and Dougherty) that the changes in blood leukocyte levels which may be seen in clinical hyperthyroidism may be the result of associated adrenal cortical insufficiency.

The removal of the thyroid gland alone caused no change in the total blood leukocyte picture. The same lack of effect of thyroidectomy on the level of total blood leukocytes and eosinophils was reported in experiments carried out by Sharpe and Bisgard, Crafts, and Simms et al. The combined removal of the gonads and the thyroid produced an increase in the total leukocyte and eosinophil counts, without change in the differential count. Simms et al. did not, however, find any change in the percentages of blood leukocytes in thyroidectomized-gonadectomized dogs.

The combined removal of the thyroid, adrenals and gonads markedly increased the level of circulating blood eosinophils, and the same procedure had a tendency to increase the level of lymphocytes. These increases were greater than noted for the thyroidectomized-gonadectomized or thyroidectomized-adrenalectomized control values. The level of blood lymphocytes and eosinophils in the thyroidectomized-gonadectomized animals was not different from values recorded for normal or thyroxine-treated adrenalectomized animals. Therefore, the results demonstrate that the removal of the gonads in the thyroidectomized animal augmented the level of blood lymphocytes and eosinophils over and above that recorded for thyroidectomized or for thyroidectomized-adrenalectomized animals. The evaluation of the significance of this observation requires further experimentation, since there are no reports to show that the sex steroids have lymphopenic or eosinopenic effect in either intact or thyroidectomized animals.

Factors Influencing the Number of Thoracic Duct Lymphocytes and the Rate of Lymph Flow (fig. 3*)

Examination of the total number of lymphocytes which enter the blood stream through the thoracic duct lymph was carried out under the experimental conditions herein described in order to elucidate in part the problem of hormonal reg-

* Values based on 6 to 9 rats/group.
ulation of the number of circulating blood lymphocytes. The results of the present investigation are discussed.

Forty days following removal of the gonads, adrenals, or thyroid, separately, or in combination with each other, the levels of thoracic duct lymphocytes were not significantly altered from control values. There was a suggested increase in the total cell content of the thoracic duct lymph following gonadectomy in the normal and thyroxine-treated animals. This effect was not observed in thyroidectomized animals.

1. Effect of adrenalectomy. Adrenalectomy had no apparent effect in altering the total cell content of the thoracic duct lymph forty days following adrenalectomy in normal, thyroxine-treated, or thyroidectomized rats. Hungerford and Reinhardt\textsuperscript{4} reported that the absolute and relative number of lymphocytes in

\begin{itemize}
\item the thoracic duct lymph was significantly increased immediately (hours) following adrenalectomy. Hungerford, Reinhardt and Li\textsuperscript{4} investigated the level of lymphocytes in the thoracic duct lymph twenty days after adrenalectomy in rats. They found that the level of lymphocytes was possibly increased, but the level was nearer to normal levels, than were the values obtained\textsuperscript{4} immediately after the operation. The total cell content of the thoracic duct lymph appears to progressively stabilize itself toward normal values after a longer time interval following adrenalectomy. Equivocal findings have been reported by Valentine, Craddock and Lawrence\textsuperscript{5} for the cat.
\end{itemize}

2. Effect of thyroxine administration or thyroidectomy. The present results indicate that thyroxine treatment or thyroidectomy have no effect in altering the cell content of the thoracic duct lymph or the flow of lymph in intact animals. The removal of the gonads or adrenals separately or in combination, in animals
that were thyroidectomized, did not alter the total cell content or rate of lymph flow of the thoracic duct lymph as compared with values obtained for normal animals.

The production of hyperthyroidism in adrenalectomized-gonadectomized animals did, however, increase significantly the rate of lymph flow and total cell count of the thoracic duct lymph over values obtained for any of the other groups studied. Apparently the production of hyperthyroidism is the major factor producing this effect, since removal of the gonads and adrenals in otherwise normal or thyroidectomized animals did not reproduce this marked increase in lymph flow and cell content of thoracic duct lymph. A suggested explanation for the cause of this phenomenon may in part reside in the observation that thyroxine treated gonadectomized animals have a tendency to a greater total cell content in the thoracic duct lymph, whereas the lymph flow is but slightly increased. On the other hand, there is a reversal of this tendency in the thyroxine-treated adrenalectomized animals, that is, increased lymph flow and a normal cell content of thoracic duct lymph. The explanation for the increased lymph flow in thyroxine-treated adrenalectomized-gonadectomized animals may be related to the fact that thyroxine treatment exaggerated all metabolic activities that would tend to increase lymph flow (i.e., greater food and fluid intake, increased metabolic rate, etc.), and that absence of the steroids of the gonads and of the adrenals allows for an exaggeration of these effects. These suggestions are also made in relationship to the investigations by Menkin, Opsahl, Sprunt, McDearman and Raper, and Kramár and Simay-Kramár which showed that the hormones of the adrenals and, to a lesser extent, the gonads play a role in regulation of fluid exchange as mediated by alterations in capillary permeability.

**Correlation of Effects**

The purpose of the following discussion is to correlate the production of lymphocytes (as reflected by a change in the weight of the lymphatic tissues), the release of the lymphocytes from these tissues into the lymph (as reflected by the number of lymphocytes in the thoracic duct lymph), and the regulation of the number of leukocytes in the circulating blood (as measured by the total and differential leukocyte counts).

In the following discussion, two assumptions are made. The first assumption holds that the number of lymphocytes entering the bloodstream via the thoracic duct represents a valid sampling of the total lymphocyte production by thymus and lymph nodes. Such an assumption neglects changes in rate of production and entry of lymphocytes into the bloodstream by other lymphatic or extralymphatic pathways. Secondly, although histologic examination of the thymus and lymph nodes were made in the present experiments, and it is possible to state that changes in weights of these tissues were not the result of edema or of distention of sinuses, yet direct mitotic cell counts were not made, hence judgments that the weights of these tissues accurately reflect cellular proliferative activity are purely arbitrary.

Gonadectomy, in the normal and thyroxine-treated animal, increased the weight of the thymus, slightly increased the weight of the lymph nodes and the number of lymphocytes in the thoracic duct lymph. The removal of the adrenals
in the normal or thyroxine-treated rat caused a marked increase in the weight of the thymus and lymph nodes; however, the increase in these tissues and their component parts, i.e., lymphocytes, was not reflected by any change in the number of thoracic duct lymphocytes entering the bloodstream as compared with control values. There does, however, appear to be a definite positive relationship between the marked increase in the weight of the lymphatic tissues, and the increase in the thoracic duct lymphocytes in adrenalectomized-gonadectomized animals receiving thyroxine treatment.

Gonadectomy slightly increased the number of thoracic duct lymphocytes entering the bloodstream, although there was no alteration in the level of blood lymphocytes. On the other hand, adrenalectomy appeared to have no marked effect in increasing the level of thoracic duct lymphocytes as compared with normal values, whereas the blood lymphocytes in the adrenalectomized animals were increased significantly over control levels. A possible explanation for this increase in the blood lymphocytes following adrenalectomy of long standing may be found in a failure of normal removal of the lymphocytes from the bloodstream, rather than in an increased delivery of lymphocytes to the bloodstream from the lymphatic tissues, as determined by sampling the thoracic duct lymph. Thyroidectomy combined with adrenalectomy and/or gonadectomy had no effect in altering the number of thoracic duct lymphocytes as compared with normal values, yet the levels of blood lymphocytes in these animals were increased over control values.

Finally it should be emphasized that although thyroidectomy vitiated the effects of adrenalectomy and gonadectomy on the weights of all lymphatic tissues, it did not alter the rate of lymph flow or the level of thoracic duct lymphocytes. On the other hand, the hypothyroid state tended to accentuate the total blood leukocyte and the total eosinophil count in the absence of adrenal and gonadal secretions, suggesting that the major effect of hypothyroidism in these circumstances was to alter the rate of utilization rather than the rate of production of these cells.

Examination of the collected data appears to indicate that quantitative variations in the weights of the lymphatic tissues are not necessarily accompanied by coincident variations in the level of blood or thoracic duct lymphocytes. This confirms in part the report by Andreasen,41 who found that the extirpation of thymus, lymph nodes, and spleen in albino rats did not alter the number of blood lymphocytes. He concluded that there was no correlation between the mass of lymphatic tissue and the level of blood lymphocytes.

**Summary**

The effects of gonadectomy, adrenalectomy, and thyroidectomy, and of thyroxine administration on the weight of lymphatic tissues and on the numbers of blood and thoracic duct leukocytes have been studied over a 40 day period in young male rats. The results of the present experiment are interpreted to indicate that:

1. Removal of the gonads caused a marked increase in the weight of the thymus, whereas but slight effect was noted on the weights of the lymph nodes.
Removal of the adrenal glands, however, resulted in a marked increase in the weight of all lymphatic tissues.

2. Thyroxine administration was demonstrated to exert a hyperplastic effect on the lymph nodes, an effect which was accentuated by the removal of the adrenals and gonads. The lymph nodes were more sensitive than the thymus to the stimulating influence of thyroxine administration in the intact animal.

3. A comparison of the weights of the thymus and lymph nodes to control values was more indicative of the hypoactivity or hyperactivity of the thyroid, adrenals and gonads, than were the weights of the thymus or lymph nodes considered separately.

4. The increase in the level of blood lymphocytes following removal of the adrenals appeared to result from a failure of normal removal of the lymphocytes from the bloodstream, rather than from an increased delivery of the lymphocytes to the bloodstream via the thoracic duct. Administration of thyroxine to normal animals did not produce a blood lymphocytosis, lending further weight to the suggestion of Marine and others that the blood changes seen in toxic hyperthyroidism are the result of adrenocortical insufficiency.

5. Changes in the weight of the lymphatic tissues were not necessarily reflected by a proportional change in the number of thoracic duct lymphocytes, nor did the number of blood lymphocytes necessarily reflect the number of lymphocytes delivered to the bloodstream via the thoracic duct lymph.

6. The marked increase in the volume and cell content of thoracic duct lymph noted in thyroxine treated adrenalectomized-gonadectomized animals appears to be directly related to an increased sensitivity to the effects of thyroxine administration in the absence of these glands.

7. Removal of the thyroid gland vitiated the increases in weight of thymus and lymph nodes produced after castration and/or adrenalectomy.

8. The eosinophilic leukocytosis consequent on adrenalectomy was markedly augmented by removal of the thyroid and gonads.

Summario in Interlingua

Esseva studiate in juvente rattos mascule e durante un periodo de 40 dies le effectos de gonadectomia, adrenalectomia, thyroidectomia, e del administratiun de thyroxina super le peso de texitos lymphatic e le numero de leucocytos del sanguine e del ducto thoracic. Le resultatos del studio es le sequent:

1. Gonadectomia causava un marcate augmento del peso del thymo, sed solo un leve efecto esseva notate super le peso del nodos lymphatic. Adrenalectomia, del altere latere, resultava in un marcate augmento del peso de omne le texitos lymphatic.

2. Esseva demonstrate que le administratiun de thyroxina exerceseva un efecto hyperplastic super le nodos lymphatic. Iste efecto se accentuava post excision del adrenales e gonades. In animales intacte le nodos lymphatic mostrava un sensibilitate plus grande que le thymo al influentia stimulante del administratiun de thyroxina.

3. Le comparation del peso combine de thymo e nodos lymphatic con valores de controlo indicava le hypo- o hyperactivitate de thyroide, adrenales.
e gonadas plus satisfacentemente que un simile comparation del pesos separate de o le thymo o le nodos lymphatic.

4. Le augmento del lymphocytes del sanguine post adrenalectomia resultava apparentemente ab un disturbance del elimination normal de lymphocytes ab le sanguine plus tosto que ab un augmentate transmission de lymphocytes via le ducto thoracic. Le administration de thyroxina a animales normal non produceva lymphocytoisis del sanguine. Isto pareva corroborar le opinion de Marine e altere autores que la cambiamentos del sanguine que se observa in hypothyroidismo toxic es le resultato de insufficientia adrenocortical.

5. Cambiamenti de peso in le teixitos lymphatic non esseva necessarimente reflectite in un cambiamento proportional in le numero del leucocytes del ducto thoracic, e similemente le numero del lymphocytes del sanguine non reflecteva necessarimente le numero de lymphocytes transmitte al sanguine via le lympha del ducto thoracic.

6. Le marcate augmento in volume e cont.eito de cellulas notate in le lympha del ducto thoracic de animales subjicite a adrenal- e gonadectomy insimul con le administration de thyroxina pare haber un relation directe con un augmentate sensibilitate al effectos de thyroxina quando le adrenales e gonades ha essite excidite.

7. Thyroidectomia contrariava le augmento de peso in thymo e nodos lymphatic que habeva resultate ab castration e/o adrenalectomia.

8. Le leucocytosis eosinophilic que sequava adrenalectomia esseva notabilmente augmentate per thyroid- e gonadectomy.

REFERENCES


ENDOCRINES, LYMPHATIC TISSUES AND LEUKOCYTES

16 Chiodi, H.: Relationship between the thymus and the sexual organs. Endocrinology 26: 102, 1940.
22 Marine, D.: Relation of suprarenal cortex to thyroid and thymus glands. Arch. Path. 1: 175, 1926.
29 Herring, P. T.: The action of the thyroid upon the growth of the body and organs of the white rat. Quart. J. Exper. Physiol. 11: 231, 1917.


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