RECEPTORS OF THE PULMONARY ARTERY IN BIRDS

by

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Little has been known concerning the sensory nerve endings of the pulmonary artery, particularly in birds. In studying the supracardial encapsulated receptors of the newly-hatched chicks, we have demonstrated some receptors morphologically similar to the aortic bodies located at the main pulmonary arterial trunk and its bifurcation (TCHENG, FU and CHEN, 1963). In the present paper, some further observations concerning this problem in other species of birds are reported.

Materials and Method

Three species of small-sized birds including the great reed warbler *(Acrocephalus arundinaceus orientalis)*, the little bittern *(Ixobrychus eurhythmus)* and the zebra parakeet *(Melopsittacus undulatus)* were used in this study. The hearts together with the adjoining great vessels of these birds were fixed in 80% alcohol containing 2% glacial acetic acid, and impregnated in toto by the method of CAJAL-FAWORSKY. Good results were obtained when the duration of fixation and impregnation was prolonged than in the original method. The blocks were then embedded in paraffin and made in transverse serial sections

Observations

In the preparations made by the method of CAJAL-FAWORSKY, the pulmonary arteries of these birds are observed to be supplied with sparsely distributed sensory nerve endings in addition to the previously reported aortic bodies found in the connective tissue between the *aorta* and the pulmonary artery (FU, CHEN and TCHENG, 1962). These receptors are seen on the surface of the main pulmonary arterial trunk, its bifurcation and the proximal portions of the right and left pulmonary arteries. They are usually round or oval and occasionally elongated a contour. Fig. 1 illustrates one of the receptors situated closely on the lateral surface of the left pulmonary artery of a great reed warbler. It appears as an oval mass composed of compactly agglomerated epithelioid cells, and covered by a connective tissue capsule. The cytoplasm of the epithelioid cells is seen to be clear or finely granular and faintly colored in the silver impregnation preparations. The strongly argyrophilic nerve fibers

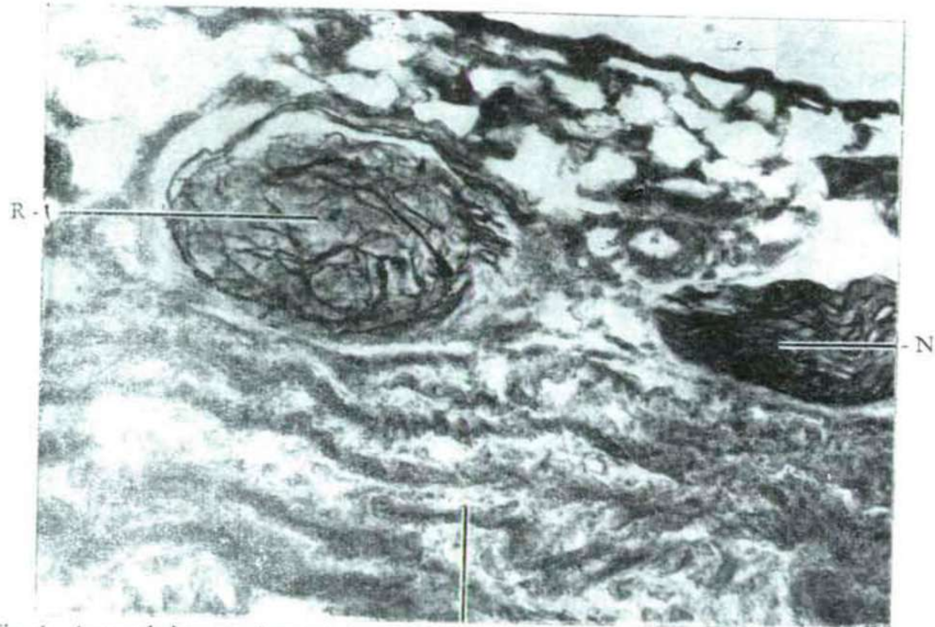


Fig. 1. *Acrocephalus arundinaceus orientalis:* An encapsulated receptor situated closely on the lateral surface of the left pulmonary artery . N — Nerve. P — Pulmonary artery. R — Encapsulated receptor. Method of CAJAL—FAWORSKY. × 540.

Fig. 2. *Ixobrychus eurhythmus:* An encapsulated receptor on the lateral surface of the right pulmonary artery. P — Pulmonary artery. a — Arteriole. v — Vein. Method of CAJAL —FAWORSKY. × 450.

in the receptor form an intricate *plexus*. At the right of the photomicrograph, a nerve which carries the sensory fibers from the receptor is demonstrated.

Fig. 2 illustrates an oblong encapsulated receptor on the lateral surface of the right pulmonary artery of a little bittern. Underneath the capsule, the epithelioid cells are divided into several groups by the connective tissue and blood vessels. The cell boundaries and the nuclear membranes of the epithelioid cells in the supracardial encapsulated receptors in the little bittern are more clearly distinguishable than those of the great reed warbler. In this photomicrograph, only few nerve fibers and their branches are seen, while the vascular bed of the receptor is remarkably demonstrated. Although the receptor is situated so closely to the pulmonary artery, no single arterial branch originated from the latter entering the receptor can be traced. The „glomic" artery of this encapsulated receptor is derived from a branch of the right coronary artery.

Similar sensory terminal structures are also found near the bifurcation of the pulmonary trunk. In Fig. 3, two round encapsulated receptors are seen between the right and left pulmonary arteries which are partly shown at the upper corners of this photomicrograph. Just underneath the capsule of the receptors, nerve fibers are observed to form periglomic plexuses along the periphery of the epithelioid cell mass. The intraglomic nerve plexuses and terminal fibers of the receptors can be traced in neighboring sections. On the left side of the receptors lies a capillary network.

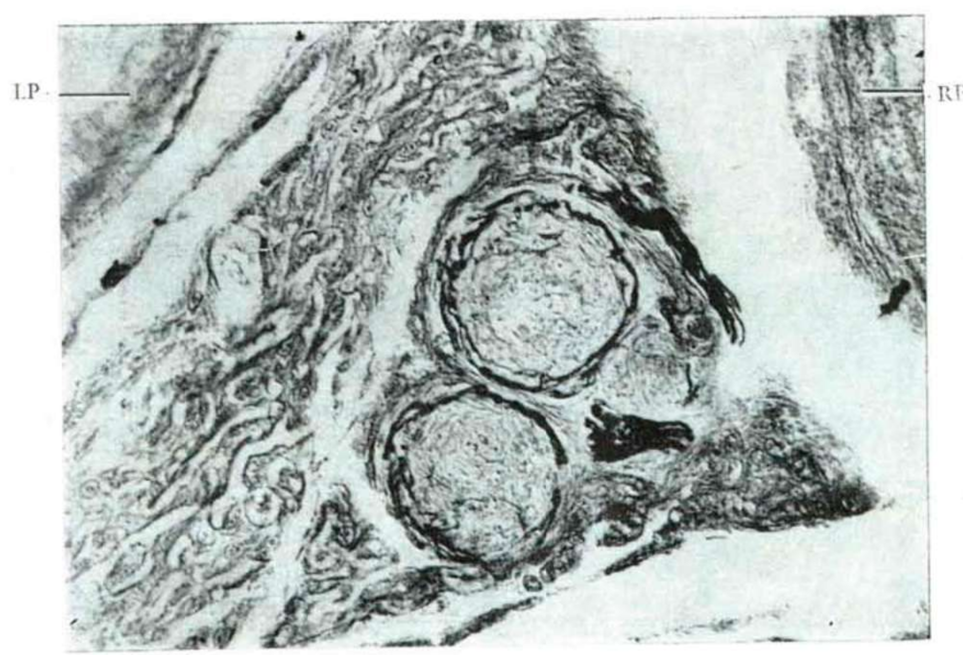


Fig. 3. *Acrocephalus arundinaceus orientalis:* Two encapsulated receptors are situated between the right and left pulmonary arteries. LP — Left pulmonary artery. RP — Right pulmonary artery. Method of CAJAL—FAWORSKY. × 450.

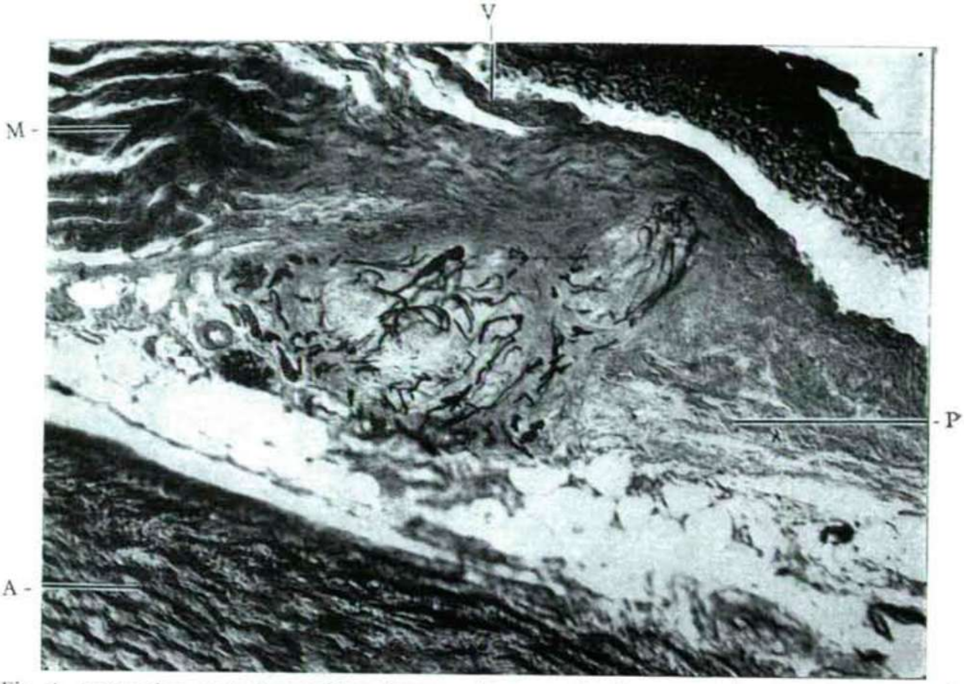


Fig. 4. *Ixobrychus eurhythmus:* Two intramural encapsulated receptors in the *adventitia* and the *media* of the pulmonary artery at its base. A — *Aorta*. M — *Myocardium* of the right ventricle. P — Pulmonary artery. V — Semilunar valve. Method of CAJAL—FAWORSKY. × 310.

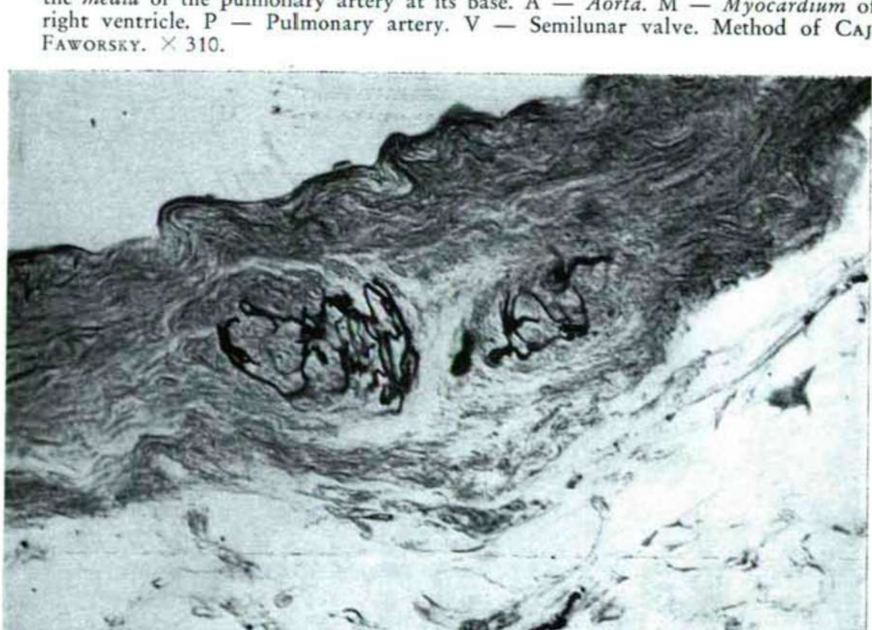
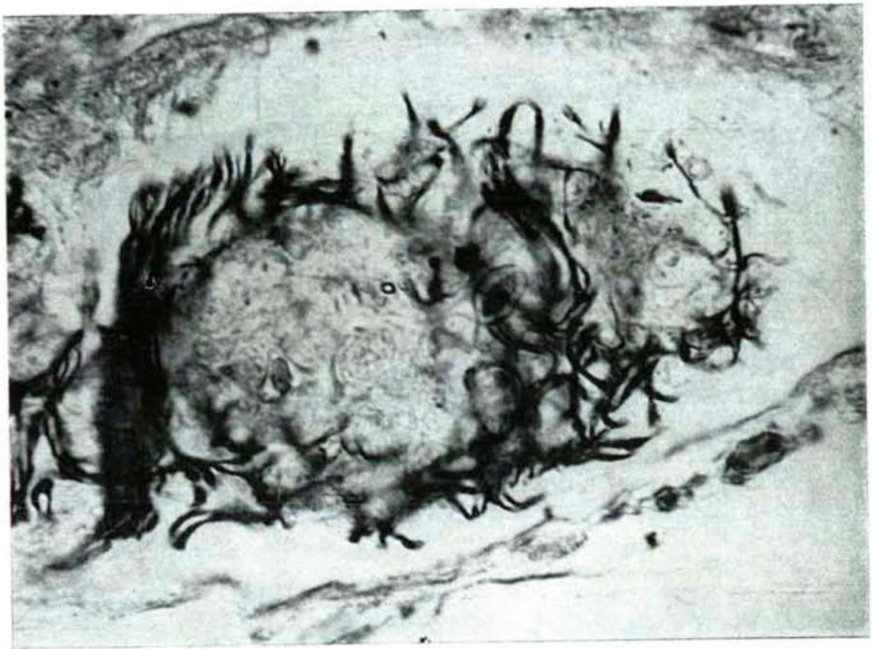


Fig. 5. *Melopsittacus undulatus:* Two intramural encapsulated receptors in the media of the right pulmonary artery. Method of CAJAL—FAWORSKY. × 540.



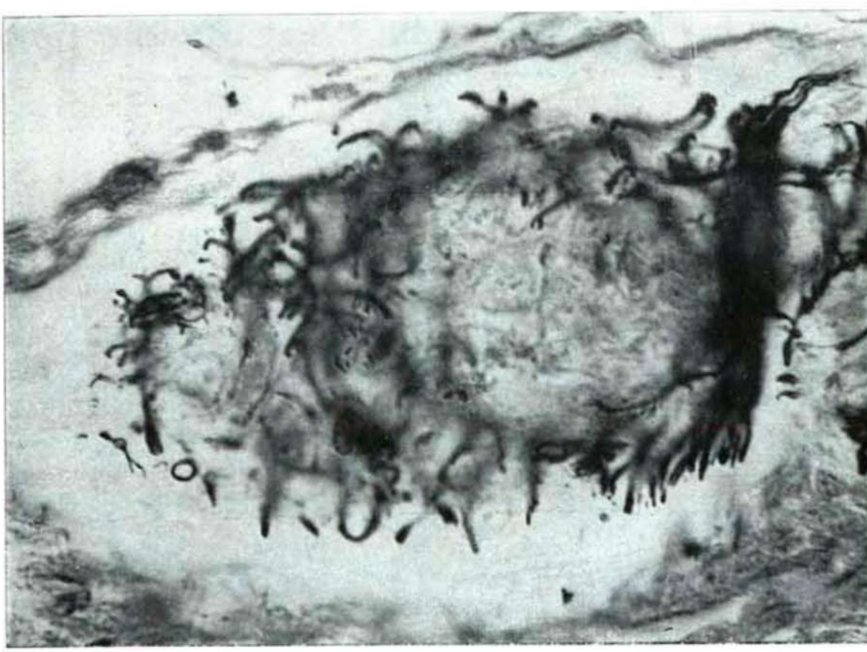


Fig. 6. & 7. *Melopsittacus undulatus:* Terminal rings in the same encapsulated receptor photographed from two planes. Method of CAJAL—FAWORSKY. × 1 200.

The encapsulated receptors are found not only on the surfaces of the pulmonary arteries but also intramurally within the wall of these vessels. It is particularly interesting to notice in Fig. 4 that two oval masses composed of faintly stained epithelioid cells extend intramurally even to the inner part of the *media* of the pulmonary artery just at its base where the semilunar valves inserted. A number of nerve fibers are seen to extend inward and to twist among the epithelioid cells in these receptors. Varicose thickenings along the course of some nerve fibers are also demonstrated in this figure. The nerve fibers may be distributed in the *adventitia* and *media* outside the capsule of the receptors, as may be observed in some of the serial sections. However, no sensory nerve fibers and their end formations are found in the semilunar valves in spite of the fact that sensory nerve fibers are found present in the *intima* of the vascular wall.

The intramural encapsulated receptors have also been found in the *media* of the pulmonary arteries near the main bifurcation. Fig. 5. illustrates such an example in the right pulmonary artery of a zebra parakeet. In this photomicrograph, two intramural receptors are demonstrated to be wellencapsulated, composed of epithelioid cells and abundant terminal nerve fibers. The repeatedly coiled course of the sensory nerve fiber in the right one is particularly evident.

The ultimate structures of the terminal fibers in the encapsulated receptors are represented as slight enlargements or in ring forms. Two terminal rings

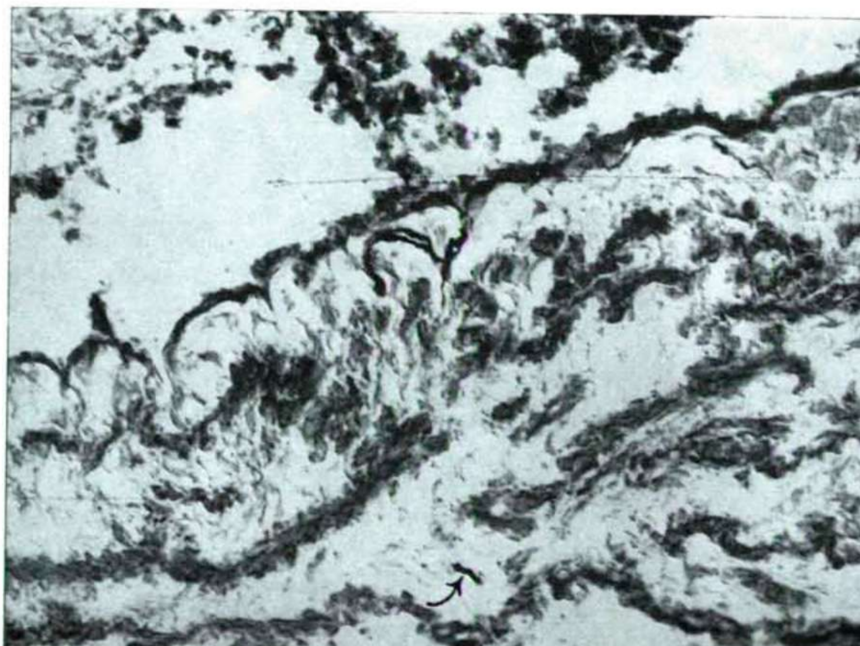


Fig. 8. *Ixobrychus eurhythmus:* Terminal sensory nerve fibers in the subendothelial tissue of the pulmonary arterial trunk. One fragment of the sensory nerve fiber is seen in the *media* as indicated by an arrow. Method of CAJAL—FAWORSKY. × 540.

found in an encapsulated receptor close to the wall of the right pulmonary artery in a zebra parakeet are illustrated in two figures photographed from two different planes (Fig. 6 and 7). We have never observed the so-called „*Terminalreticulum*" as the nerve end-formation described by SUNDER-PLASSMANN (1938) in human pulmonary artery and by STÖHR (1954) in the *paraganglion*.

All the above mentioned sensory nerve endings belong to the encapsulated type. The free nerve endings of sensory nerve fibers are, however, also found in the vascular wall of the pulmonary arteries. They are usually observed in the *adventitia* and the *media*, and only occasionally in the *intima*. As demostrated in Fig. 8, a terminal fiber divides twice in the subendothelial connective tissue. One fragment of a sensory nerve fiber indicated by an arrow in this photomicrograph is seen in the *media;* it can be followed to be continuous with the subendothelial terminal fibers coursing straightly toward the intima.

Discussion

Although the innervation of the pulmonary vessels had been studied by a number of histologists (KARSNER, 1911; LARSELL and DOW, 1933; GAYLOR, 1934; NONIDEZ, 1937; SUNDER—PLASSMANN, 1938; ELFTMAN, 1943; etc.), reliable data concerning the structure of the receptors in the proximal portion of the pulmonary artery are lacking. The results of the present investigation would give some light to the problem. It may not be out of place to consider the functional significance of our present findings.

In their book „Reflexogenic areas of the cardiovascular system", HEYMANS and NEIL (1958) stated that there is a steady accumulation of evidence that the pulmonary veins possess a sensory innervation which represents the end of the afferent armo f cardiovascular and respiratory reflexes. On the other hand, the function of receptors in the pulmonary trunk or pulmonary arteries has less been satisfactorily studied. From morphological studies, numerous pressoreceptors are observed at the base of the pulmonary veins in the cat, dog and rabbit, while they are not usually found in the pulmonary artery in most of the mammals studied by NONIDEZ (1937, 1941). Although sensory nerve endings are discovered in the proximal part of the pulmonary artery in birds, they are very scanty and sparsely distributed. These facts may explain why the pressoreceptors in the pulmonary veins are more easily detected in physiological experiments.

The presence of baroreceptors in the proximal part of the pulmonary artery has been demonstrated by some recent physiological studies. AVIADO and his collaborators (1951) produced reflex *bradycardia* when the first part of the pulmonary artery was exposed to the rise in pressure. LEWIN et al (1961) found that the constriction of the systemic arteries occured when the main pulmonary artery was distended proximal to its bifurcation. By an electrophysiological means, COLERIDGE and KIDD (1960) were able to localize the afferent nerve endings situated in the walls of the pulmonary artery in the region of the main bifurcation and in the extrapulmonary portion of the right and left branches, but not in the main pulmonary trunk proximal to its bifurcation. Even if the results obtained by these physiological experiments are not accord in every aspect, all of their positive findings concerning the location of baroreceptors are confirmed by our morphological investigation. The intramural receptors in the proximal part of the pulmonary artery — both encapsulated and free-arborization types, might be considered as baroreceptors quite sensitive to the pressure changes in the vascular wall. It is particularly interesting to note the presence of the intramural encapsulated receptors in the wall of the pulmonary artery at its origin from the right ventricle. They may be sensitive to the pressure difference between the cardiac and the pulmonary circulation. However, the sensory nerve plexuses in the pulmonary semilunar valves which had been demonstrated by LIPP (1951) with the methylene blue technique are not found in our preparations with birds.

The encapsulated receptors located at the vicinity of the main bifurcation and on the lateral surface of the proximal portions of right and left pulmonary arteries may be considered as pressoreceptors, assuming that these are the structures which have been localized as pressoreceptors from the physiological experiments by COLERIDGE and KIDD. Morphologically, they are identical to the encapsulated receptors found in the connective tissue between the *aorta* and the pulmonary arterial trunk corresponding to the group 4 of the aortic bodies described by HOWE (1956) in the cat. It may be suggested that these structures possess, in addition, a chemoreceptive function. Be it so, they are considered to be sensitive to the chemical changes of the blood leaving the left ventricle, judging from the fact that the vasculature of these receptors is derived from the coronary arteries. They may not be sensitive to the blood changes of the pulmonary artery as no arterial branches from the latter are seen to enter the receptors in spite of their close association. It is, thus, supposed that the encapsulated receptors in this region may have a dual function — a baroreceptive function, sensitive to the changes of the pressure of the pulmonary artery, and a chemoreceptive one, sensitive to the changes of the constituents of the arterial blood from the left ventricle.

Since the physiological investigations cited above are carried on with the dogs, more appropriate interpretations of our present results may be obtained by future experimentations on birds.

Summary

With the method of CAJAL-FAWORSKY, sensory nerve endings are demonstrated in histological preparations to be sparsely distributed in the proximal part of the pulmonary artery in birds. Encapsulated receptors which are morphologically identical to the aortic bodies are found at the main bifurcation and on the lateral surface of the right and left pulmonary arteries. Two types of sensory nerve endings are observed intramurally in the wall of the proximal part of the pulmonary artery. The terminal fibers of the arborization type are usually found in the *adventitia* and the *media,* and only occassionally in the *intima.* The intramural encapsulated receptors found in the *adventitia* and the *media* of the pulmonary trunk at the site of its junction with the right ventricle are of a particular importance. The significance of these findings has been discussed.

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