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Hormonal Regulation in Animals

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Abstract

Hormonal regulation is an essential biochemical process for the life of the animal organism. This document is a bibliographic review article whose objective was to analyze hormonal regulation in animals, taking as a reference cell as a morphological, physiological, genetic and reproductive entity of any living being. For this, an exhaustive documentary investigation was carried out regarding the subject matter, where the most suitable articles were chosen from scientific journals indexed in various international repositories (Scielo, Latindex, Elseiver). The body of the article consists of two fundamental sections which are: hormonal regulation at the cellular level and the importance of hormonal concentration. The analysis of the documents shows that hormones exert a local and systemic effect at the organic level through biochemical signaling in the H-R complex, which has a decisive impact on cell physiology. According to the results of the review, it is concluded that hormonal regulation allows channeling metabolic or physiological mechanisms at the cellular and tissue level, through feedbacks of increasing and decreasing plasma concentrations at the blood level, and through the HR Complex for homeostatic maintenance necessary for life.

Keywords

Cell, endocrinology, physiology, hormone

1. Introduction

Hormones represent a diversity of biomolecules of great physiological relevance, since the activation of mechanisms of biochemical cascades at the cellular and tissue level depends on them. Scientists increasingly look at hormone regulation processes and biosynthesis phases to determine more accurate and timely medical diagnoses. Various clinical trials are carried out in laboratory animals to study hormonal behavior according to specific pathologies and previously defined variables, to later be applied in humans [1].

Even from fetal development, chorionic hormones begin to exert a direct effect on the natural cellular mechanisms of the embryo and after birth, the pituitary gland takes over general control of the organism, manufacturing stimulating hormones for all the rest of the glandular tissues. In the current field of animal endocrinology, hormones have played a crucial role from the cellular point of view as organic modifiers and even as therapeutics in meat and dairy production in species of zootechnical interest (cattle, goats, pigs and sheep). Since new metabolic findings have been discovered at the systemic level (example: somatotropin, type I insulin-like growth factor, leptin, among others). These hormones favor the metabolism of carbohydrates in myocytes and the availability of essential amino acids for protein synthesis, cell reproduction and prevent plasmolysis [2]. According to the above, hypertrophy and hyperplasia are affected when hormones come into contact with their respective cytoplasmic or endoplasmic receptor, since the metabolic and genetic machinery directs its actions to the response of the catalytic site of the H-R Complex.

The objective of this article was to analyze the hormonal regulation in animals taking as a reference cell as a morphological, physiological, genetic and reproductive entity of any living being and some simple examples are mentioned for a better understanding. The document is divided into two sections: hormone regulation at the cellular level and the relevance of hormone concentration. The last are the conclusions and references products of this work.

2. Methodology

This study was framed in a non-experimental field design, since no variables were intentionally manipulated. Likewise, an exhaustive bibliographical review of different documents collected and selected according to the theme proposed in this work was carried out, taking as reference the title, summary and introduction of the chosen works. Then we proceeded to the total analysis of the content of the chosen articles [3].

2.1 Hormone regulation at the cellular level.

Hormones are specialized heterogeneous molecules that, secreted in small concentrations, cause a certain effect in a specific tissue or organ of the animal organism. These are located in small organs called "endocrine glands" (without ducts), or by some cells of the epithelial or interstitial tissue in order to affect neighboring cells, that is, those that are around the same tissue [4].

These molecules have the characteristic of acting on the target cells, that is, tissue or organ with specific receptors for a certain hormone. There are two varieties of cell receptors [5].

(1) Cytoplasmic membrane receptors: they are used by protein hormones (those composed of long-chain amino acids). These glandular products bind to a compatible receptor in the plasmatic membrane of the animals, promoting the activity of another protein (reaction or catalysis unit), which transforms ATPi (Intracellular Adenosine Triphosphate) to AMP (Adenosine Monophosphate), which together with intracellular calcium (cofactor), it activates an enzyme called protein kinase, which is responsible for producing the phosphorylation (aggregation of phosphate groups for the generation of endogenous energy) of cellular proteins through a cascade, which produces an action determined biological.

(2) Intracellular receptors: they are used by steroid hormones (cholesterol, progesterone, among others), which cross the cell membrane by a diffusion mechanism. Once inside the cytoplasm, it even penetrates the nucleus, where it binds to DNA (deoxyribonucleic acid) and causes mRNA (messenger ribonucleic acid) to be synthesized, which induces the synthesis of new proteins, which will result in a physiological response according to the produced molecule.

Hormones, once secreted, travel through the circulatory system through the plasma from the endocrine gland that originated them, to the cells specialized in receiving the message (target organ) inscribed in its molecule by means of well-determined chemical signals. The cells that make up a target organ have specific receptors in which they only interact with specific hormones, so that each hormone communicates only with a specific type of target cell, whose receptors are compatible for said hormone, forming the Hormone-Receptor Complex (H-R), where chemical instructions are transmitted for the physiology of the receiving tissue [6].

During its journey through the blood plasma (liquid phase of the blood that hormones and other molecules use as a means of movement), some exclusive molecules bind to various hormones to be transported. These proteins act as biological controllers, modulating the concentration of available hormone that must interact with the target cells. The number of receptors in the cell does not seem to remain constant, but a hormone can, by fixing itself to the receptor, produce a decrease or increase in the biological activity in the catalytic site of these; or, on the contrary, the hormone-receptor union, promoting the anabolism of other cellular intercommunicators [7].

The first of these mechanisms is called "down-regulation" where the amount of receptor proteins decreases, derived from a response by the target organ to the hormone. On the other hand, the second is called "up-regulation" of the proportion of receptor proteins, causing an increase in the sensitivity of cells to the interaction with the hormone. Once the H-R Complex is formed, a cascade of biochemical events take place in the organism, causing a specific cellular excitation as a response to the initial stimulus [8].

The lipid bilayer of the cell membrane is highly dynamic, because it has hydrophilic and hydrophobic ends, so the proteins associated with it, such as those related to hormone receptors, can move quickly, increasing the contact surface between the H-R Complex, avoiding certain pathologies such as diabetes. Some hormones of protein origin can enter the cell after binding to the membrane receptor, this does not mean that it is a late process, there is simply an endocytic process due to cell invagination, that is, a change in the configuration of the membrane occurs. Plasma that is coupled to the size of the hormonal molecule, and this is covered by the membrane in the form of a vesicle, thus entering the cell protoplasm [9].

2.2 Importance of hormone concentration and pleiotropic effect.

When hormonal plasma concentrations reach normal values (according to the values for a given hormone and environmental conditions), the endocrine system through homeostasis helps the body to maintain reference values in the

blood plasma. For example, in bovines the concentration of T3 (triiodothyronine) is 1.80-1.90 nmol/L and T4 (thyroxine) is 42-160 nmol/L. In humans, T3 is 45-60 nmol/day and T4 is 100-130 nmol/day. This shows that the normal daily concentration depends on the specimen [10].

If the thyroid gland has secreted the proper concentration of T3 and T4, the animal's mother organ (pituitary) captures the normal concentration of that hormone in the bloodstream, adjusting the release of thyrotropin, the pituitary hormone that stimulates the thyroid gland, to produce thyroid hormones [11].

A comparison of these interactions is found in the parathyroid glands. The optimal physiological levels of this hormone are between 14.5 pg/mL- 87.1 pg/mL. Parathyroid hormones regulate the concentration of the mineral calcium in the blood. When the serum concentration of this mineral is very high, the parathyroid glands capture the change and, consequently, reduce the secretion of said hormones. This interactive flow of homeostatic adjustment is called the negative feedback system [12].

Another interesting situation is the estradiol levels in the follicular fluid. These correspond to the overall quality of the follicle, relating its concentration to the number of granulosa cells. Instead, the levels of the female sex hormone progesterone are related to the maturity of the secondary oocyte and the degree of luteinization of the Graafian follicle. In addition, estrogens were found to be actively involved in the formation of kidney tissue, specifically in the epithelium of the renal tubules, and in the regulation of hydroelectrolytes such as sodium [13]. This indicates a pleiotropic effect of this family of female sex hormones on the urinary tract, meaning that the hormone has an effect on various target organs or tissues.

Likewise, the plasma values of male steroid substances (androgens) have been used as a quality variable related to the maturation of follicular ova, finding that testosterone levels decrease significantly in the follicular fluid of fertilized oocytes [13].

There is another hormone such as insulin-like growth factor I (IGF-I), which is a molecule with an atomic mass of 7.5-kDa that promotes hyperplasia (cellular reproduction) and differentiation, making it essential for normal growth and hypertrophy (development and increase of cell protoplasm) [4].

IGF-I seems to have a key role in the growth of myoblasts (muscular system cells), since it stimulates their differentiation to form mature tissue. It also favors the uptake and assimilation of amino acids for protein synthesis at the muscle level [14].

On the other hand, growth hormone or somatotropin (GH) is an anabolic amino acid macromolecule, because it stimulates protein biosynthesis, therefore it has a synergistic effect with IGF-I [15]. Another novel study carried out in rodents [16], demonstrated that the administration of IGF-I caused greater growth in hypophysectomized rats (surgical removal of the pituitary gland) compared to those rats that were administered GH.

Trials in rats have verified that the local administration of GH in specific bones, such as that of the hind limbs, increases said organ without compromising the rest of the skeletal system. This finding suggests that GH stimulates bone growth *in vivo*[16].

It has also been found that GH stimulates DNA synthesis in rabbit ear chondrocytes and rat cartilage, allowing the reproduction and growth of said cells that form bone and cartilage tissue [17]. Similarly, Spanish researchers in 2019 made a crucial discovery, they detected that GH and IGF-I are capable of regenerating neuronal tissue in rats, and also intervene in learning capacity when they are hypersecreted [18]. These findings show that these hormones contribute to various tissues (muscular, neuronal, bone), which refers to a well-defined pleiotropic effect. For this reason, these two hormones are still under study at present, due to their influence at a systemic level.

In vitro studies with the diaphragm muscle of rats have shown that GH directly stimulates amino acid uptake and glucose transport to the diaphragm muscle. These results are of vital importance, since GH implicitly promotes the displacement of sugar towards the organs that it directly affects. This suggests that there is an important mechanism for the supply of carbohydrates at the muscle level [19]. Sugar is the biological fuel par excellence used by cells in aerobic and anaerobic cellular respiration, if there are no adequate concentrations of glucose or glycogen in the blood, the cells resort to fatty acids (as occurs in ruminant animals) or failing that by muscle proteins. Being the main reason that explains weight loss in animals when they are subjected to physiological stress or some pathology [2].

In animals of zootechnical interest such as cattle, sheep, goats and pigs, they have used IGF-I and GH to produce animals with greater muscle mass, this causes marbling (intramuscular fat) to be reduced, because the growth of the Muscle tissue is inversely proportional to fat tissue, that is, the greater the proportion of muscle, the lower the fat, so meat has less fat and is more palatable to consumers [20]. In Europe and the United States, it is where these livestock practices are carried out

with the highest proportion, even to raise animals with double muscles.

We have an example of this in the Belgian *blue*, a breed of cattle with surprising musculature. Although this condition is hereditary in this breed, exogenously administered GH and IGF-I can cause this effect as a result of hyperplasia and hypertrophy of muscle fibers, if they are administered from an early age in animals [20, 21].

In addition, they have been used effectively to increase milk production in cattle herds. When the female is pregnant, the mammary gland genetics is expressed in such a way that for some researchers such as [22, 23, 24] the rest of the animal's body becomes an appendage of the gland. This makes it clear that the anabolic processes at the udder level come to the forefront of the physiology that, in extreme cases, the mammary gland is capable of using muscle protein to catabolize it and thus obtain the necessary energy for the anabolism of the udder milk protein.

Everything previously described in this section demonstrates the pleiotrophic effect of these hormones. For this reason, scientists have tried to study them under different conditions to record their behavior and the effects on experimental animals.

3. Conclusions and Recommendations

After analyzing the findings found in the literature review on the subject, the following can be concluded:

Hormones are organic molecules that have an amino acid or steroid nature, capable of stimulating a local or systemic response in the body. For this reason, they are fundamental in the organic homeostatic balance. Likewise, the H-R Complex is essential to establish contact surfaces that allow the catalytic and biological action of the cascades involved in any H-R interaction.

Hormonal regulation through its transporter molecules in the blood plasma, allows modulating the concentration of hormones on a daily basis. Recent studies on the various effects of hormones are still undergoing experimentation, due to the generalized pleiotropic effect of many of them on cell physiology and homeostatic adaptation of animals to their variations on target organs and/or tissues. Currently, GH and IGF-I are still under study, since they not only have a synergistic influence on growth, but also affect a variety of tissues, implicitly implying that these hormones have a diversity of cellular receptors that still exist. They are not fully identified.

Therefore, the investigations that contribute new findings are of great relevance to continue in the search for feasible medical solutions for patients suffering from a congenital or chronic disease derived from hormonal action.

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