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Bridging Biology: A Comparative Study of Hormonal Regulation in Plants and Humans

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Abstract
This study provides fundamental insights into the role of growth hormones in both plants and humans. Each hormone serves a unique function, contributing not only to growth but also to various physiological activities. In plants, these hormones are referred to as phytohormones or Plant Growth Regulators (PGRs). They are categorized into two groups: ***growth promoters*** *(such as Auxins, Gibberellins, and Cytokinins) and* ***growth inhibitors*** *(including Abscisic Acid and Ethylene). These hormones regulate essential processes like cell division, elongation, flowering, and stress responses. In humans and animals, hormones are secreted by endocrine glands and transported through the bloodstream to specific target organs or tissues, where they trigger responses. The endocrine glands include the* ***pituitary, thyroid, parathyroid, adrenal, thymus, pancreas, and gonads****, each playing a crucial role in growth regulation and other physiological functions. On the other hand,* ***exocrine glands****—such as sweat, salivary, mammary, lacrimal, sebaceous, and mucous glands—release their secretions directly to target sites through ducts. These secretions aid in processes like digestion, lubrication, and thermoregulation. Thus, both plant and animal hormones are essential in maintaining growth, development, and overall homeostasis.*
Keywords: *Hormones, Promoters, Inhibitors, Somatostatin and Ghrelin.*

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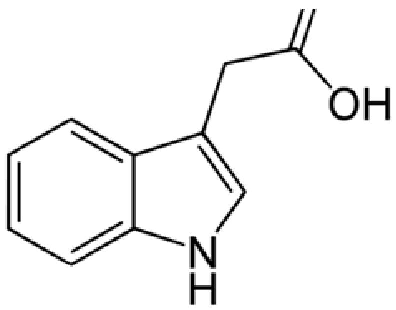
I. Introduction to Plant Growth Regulators

With the global population expected to reach 10 billion by 2050, the demand for increased agricultural productivity will also rise. This calls for better conservation of arable land to counteract the negative climate impacts associated with a growing population. Advancements in agricultural technology continue to help farmers enhance crop yields in a more sustainable and profitable manner. However, before looking ahead to future innovations, it's essential to revisit an important agricultural tool from the past—Plant Growth Regulators (PGRs). For over a century, both natural and synthetic Plant Growth Regulators (PGRs) have been used to enhance crop productivity and quality. While plants require oxygen, water, sunlight, and nutrients for their growth and development, they also produce certain chemical substances known as plant growth regulators or phytohormones. These organic molecules regulate various physiological processes, either accelerating or inhibiting plant growth.

Structure of 1)Auxin, 2)Gibberellins, 3)Cytokinins, 4)Abscisic Acid, 5)Ethylene



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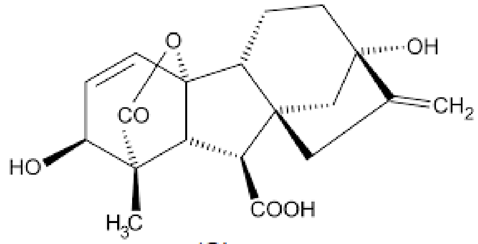

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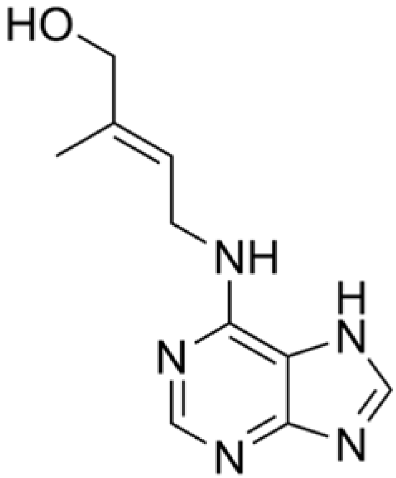

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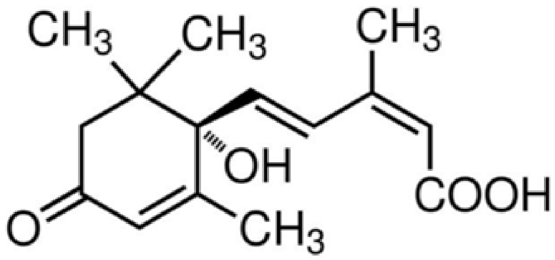

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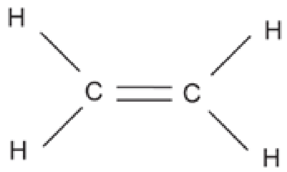

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Characteristics and Classification of Plant Growth Regulators

Plant growth regulators control several vital processes including cell differentiation and elongation, leaf and flower formation, wilting, fruit ripening, seed dormancy, and germination. They are classified into five major types based on their primary actions and chemical nature: **auxins**, **gibberellins**, **cytokinins**, **abscisic acid**, and **ethylene**.

Plant Growth Promoters

Auxins

Auxins were the first plant growth regulators discovered and chemically isolated in the 1930s. Dutch scientist **Frits Warmolt Went** first described auxin's role in phototropism, and later, **Kenneth V. Thimann** isolated the compound, identifying it as **indole-3-acetic acid (IAA)**. Their joint publication *Phytohormones* in 1937 marked a significant advancement in plant physiology (Lohani *et al.,* 2004).

Derived from the amino acid tryptophan, auxins regulate numerous processes including cell elongation, root formation, and apical dominance. The highest concentrations are found in meristematic regions, from where they move towards the roots, guiding growth via a concentration gradient (Rahman, 2013). Auxins also facilitate phototropism by accumulating on the shaded side of the plant, causing cell elongation and directional bending toward light (Lee *et al.,* 1998). Additionally, auxins promote flowering, fruit development, and bulb formation (Bawa *et al.,* 2000). Synthetic auxins have been widely used in agriculture to enhance growth and crop productivity (Kulikowska *et al*., 1995).

Biochemically, auxin synthesis involves the removal of amino and carboxyl groups from tryptophan, followed by the addition of a chloride ion, forming the active compound IAA.

Gibberellins

Gibberellins (GAs) are another class of plant hormones involved in stem elongation, seed germination, flowering, and enzyme induction. Over 70 gibberellins have been identified, with **GA_3 (Gibberellic acid)** being the most widely utilized in agriculture. Gibberellins are diterpenoids and function based on variations in their side chains (Matsuoka, 2003).

These hormones promote stem elongation even in genetically dwarf plants by stimulating internode elongation. For example, dwarf pea and maize varieties can attain normal height when treated with GA (Bawa et al., 2000). Gibberellins also play roles in breaking seed and bud dormancy, and in inducing flowering in biennial plants. They regulate gene transcription by targeting DELLA proteins through ubiquitination and proteasomal degradation, enabling growth-related gene expression (Sun and Gubler, 2004).

In agriculture, gibberellins are used for promoting seed germination, fruit enlargement (e.g., in grapes), inducing male flower production in cucumbers for hybridization, and overcoming genetic dwarfism (Lu *et al.,* 2014; Phillips *et al*., 1995).

Cytokinins

Cytokinins, discovered by **Folke Skoog** in the 1940s, are adenine-derived compounds that promote cell division and delay senescence. They exist in two forms: **adenine-type cytokinins** (e.g., kinetin, zeatin) and **phenylurea-type cytokinins** (e.g., thidiazuron). They are primarily synthesized in roots and transported via the xylem to other plant parts.

Cytokinins stimulate mitosis by enhancing protein synthesis, contributing to growth and regeneration. They balance the effects of auxins, particularly in shoot and root development (Kurakawa *et al*., 2007). Cytokinins also improve crop yield, enhance drought resistance (Taverner *et al*., 1999), and support plant immunity (Sýkorová *et al*., 2008). Their action is often visualized as the addition of building blocks to a structure, facilitating organized growth.

Plant Growth Inhibitors

Abscisic Acid (ABA)

ABA is a key inhibitory hormone that regulates seed dormancy, bud dormancy, and stress responses. Synthesized in response to environmental stresses such as drought, salinity, and cold, ABA triggers stomatal closure by affecting guard cell turgor, reducing water loss through transpiration (Karssen *et al*., 2009).

In preparation for winter, ABA inhibits vascular cambium activity and promotes the formation of protective bud scales (Mattsson *et al*., 2013). It plays a crucial antagonistic role to gibberellins by preventing premature seed germination, ensuring seeds sprout only under favorable conditions (Wilkinson and Davies, 2010; Zhang *et al.,* 2010). ABA is also essential in somatic embryogenesis and in enhancing plant survival during abiotic stress (Wijayanti *et al.,* 1997; Tardieu *et al.,* 2010).

Ethylene

Ethylene is a gaseous hormone involved in a wide range of processes including fruit ripening, senescence, abscission, and stress responses. Historically, ethylene has been used for ripening fruits as early as ancient Egypt and China (Lelièvre *et al.,* 1998). It is produced in all plant organs and has unique regulatory effects on plant growth (Lin *et al*., 2008).

Ethylene inhibits longitudinal growth while promoting lateral expansion. It modifies gravitropic responses, accelerates senescence, and promotes abscission through hydrolase activity (Noh and Amasino, 1999; Llop-Tous et al., 2000). Ethylene also promotes apical dominance, induces flowering in certain species, and breaks dormancy in seeds and tubers (Penarrubia *et al*., 1992; Lin *et al*., 2009).

In agriculture, ethylene is used to induce ripening in climacteric fruits like bananas, mangoes, and tomatoes. It also enhances sex expression in cucumbers, encourages early sprouting, and assists in fruit thinning to improve quality and yield (Wang *et al*., 2013; Masood *et al*., 2012; Noushina *et al*., 2017).

HUMAN GROWTH REGULATORS

INTRODUCTION

Growth hormone (GH) is an affiliated hormone secreted in the hypothalamus and released episodically by the anterior pituitary from **somatotroph cells**. The primary structure of human **GH** was first proposed in 1969 [Li *et al.,* 1969]. **GH** is a single-chain protein composed of 191 amino acids with a molecular weight of approximately ~22 kDa. Human **GH** is a major regulator of linear growth, cell production, and cell regeneration, and it also participates in the regulation of protein and fat metabolism. The **GH** molecule is synthesized, stored, and secreted by **somatotroph cells** of the anterior pituitary under the control of a variety of hormonal agents, including **Growth Hormone Releasing Hormone (GHRH)**, **Somatostatin**, **Insulin-like Growth Factor I (IGF-1)**, thyroid hormones, and glucocorticoids [Herman *et al.,* 1995]. It also increases the concentration of glucose and free fatty acids [Ranabir & Reetu, 2011][Prtronella & Drowin, 2011].

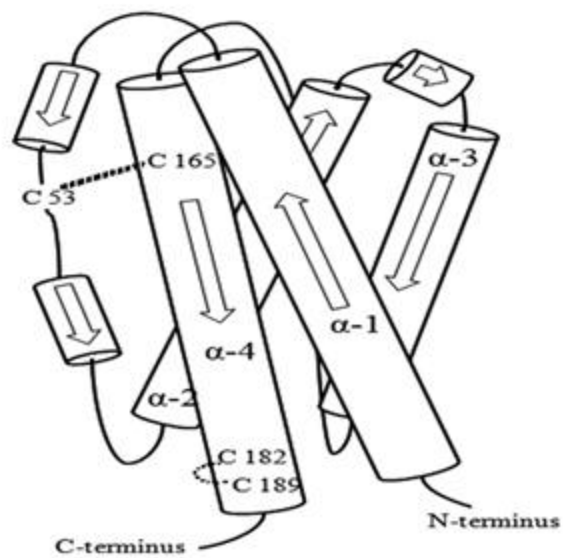
BIOLOGY

GENE: In humans, the q22-24 region of chromosome 17 (17q22/24) forms a locus that comprises five genes, of which two are **GH** genes and three are placental lactogen (PL) genes. The **GH** gene cluster consists of two **GH** genes, i.e., **GH1** and **GH2**, while the PL gene cluster comprises **CSH1** (chorionic somatomammotropin hormone 1), **CSH2**, and **CSHL** (chorionic somatomammotropin hormone-like). **GH1** codes for the predominant **growth hormone** in adults, which is produced in the **somatotroph cells** found primarily in the anterior pituitary gland and to a lesser extent in lymphocytes. **GH2** codes for **placental growth hormone**. The PL genes code for **chorionic somatomammotropins** (**CSH1**, **CSH2**, and **CSHL**) [Baumann, 2012]. **CSH1** and **CSH2** genes encode polypeptides that differ by a single amino acid, and both differ by 32 amino acids from the **GH1** gene. Gene conversions between these different genes may result in altered expression patterns or functions.

STRUCTURE

The X-ray crystallography of **GH** in complex with the **GH receptor (GHR)**, as demonstrated by de Vos and colleagues, provided critical insights into the 3D structure of human **GH** [de Vos *et al*.,1992]. The major structural feature of the human **growth hormone (HGH)** is a four alpha-helix bundle organized in an unusual up–up–down–down topology, which is characteristic of the hematopoietic factor family of peptides. The N-terminal and C-terminal helices (helices 1 and 4 containing 26 and 30 residues, respectively) are longer than the other helices (helices 2 and 3 containing 21 and 23 residues), and each is connected by three additional mini-helices. The core of the four α-helix bundle is primarily composed of hydrophobic amino acids, which contribute to the stabilization of the structure. The 3D conformation is also stabilized by two disulfide bonds between cysteine residues C53–165 and C182–189, in addition to several hydrogen bonds between various amino acid residues [Fig. 1].

Figure 1: Structure of human Growth Hormone



MECHANISM OF ACTION

Pituitary synthesis and secretion of **GH** is stimulated by episodic release of hypothalamic hormones. **Growth Hormone Releasing Hormone (GHRH)** stimulates, while **somatostatin (SST)** inhibits **GH** production and release. The gastric peptide **ghrelin** is a potent **GH** secretagogue that acts to amplify hypothalamic **GHRH** secretion and synergizes with its pituitary **GH**-stimulating effects [Kargi *et al*., 2013].

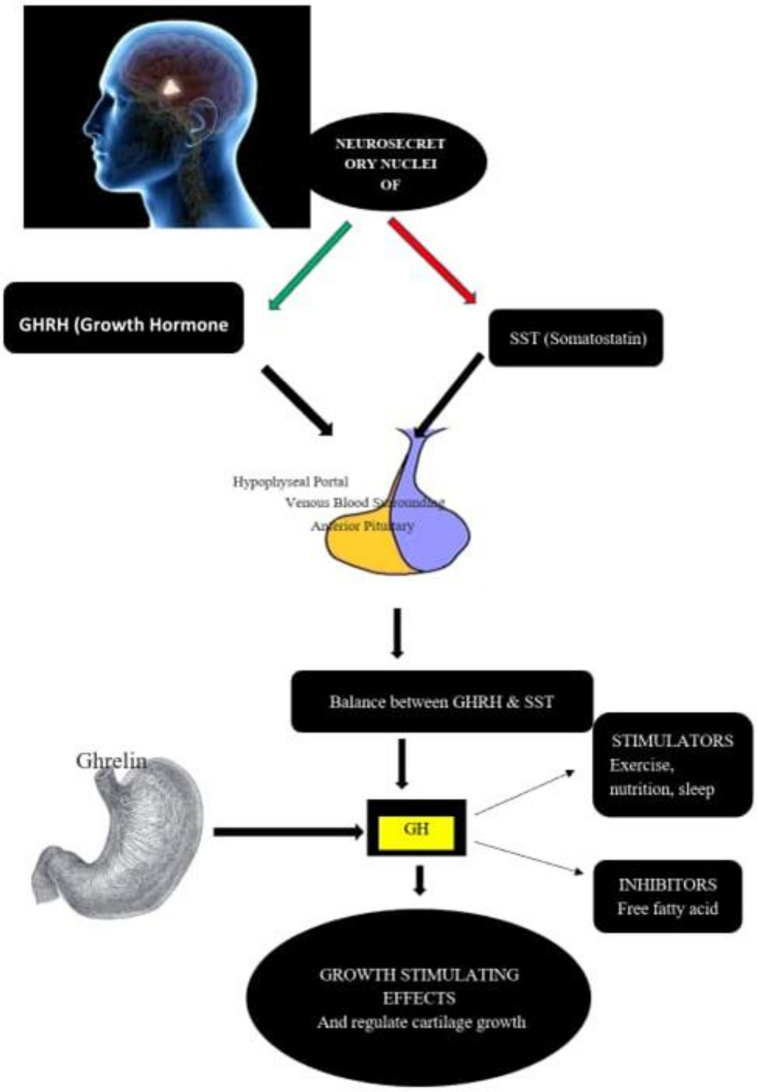
SOMATOSTATIN (SST):

SST is a cyclic peptide, encoded by a single gene in humans, which predominantly exerts inhibitory effects on endocrine and exocrine secretions. Specifically, it inhibits **growth hormone (GH)** production and release by acting directly on **somatotroph cells** of the anterior pituitary [Ren *et al*., 2003].

GHRELIN

Ghrelin is a 28-amino-acid peptide and the natural ligand for the **GH secretagogue receptor**. It is primarily secreted by the stomach and binds to receptors on **somatotroph cells**, potently stimulating the secretion of **growth hormone**. In fact, **ghrelin** and **GHRH** have a synergistic effect in increasing circulating **GH** levels [Ribeiro & Barkan, 2011]. **Ghrelin** is also involved in the regulation of appetite, fasting, and food intake.

Fig. 2: Flowchart of Growth hormone synthesis and regulation:



II. FUNCTIONS

The function of **GH** is widely recognized for its effect on increasing height during childhood, where **GH** exerts an anabolic effect by binding to specific receptors on the cell surface responsible for growth. This action is initiated by two mechanisms. **GH** is a polypeptide hormone and is not fat-soluble, so it cannot penetrate the cell membrane. As a result, **GH** exerts its effects by binding to surface receptors and activating the **MAPK/ERK**

pathway (Mitogen-Activated Protein Kinase / Extracellular-signal-Regulated Kinase), a cascade of proteins that transmits signals from the cell surface to the DNA in the nucleus [Orton *et al*., 2005]. Through this pathway, **GH** directly stimulates cell division and the multiplication of chondrocytes in cartilage. Additionally, **GH** stimulates the production of **IGF-1** via the **JAK/STAT pathway** (Janus Kinase / Signal Transducer and Activator of Transcription), which plays a key role in gene transcription [Aarosan & Horvath, 2002]. **IGF-1** further enhances osteoblast and chondrocyte activity to promote bone growth (Fig. 2).

CLINICAL SIGNIFICANCE
Alterations in **growth hormone** levels—either excess or deficiency—lead to distinct physiological conditions.

Fig. 3: Growth Disorder: Gigantism & Dwarfism

Excess: Excessive **GH** secretion is age-dependent and results in two distinct disorders. **Gigantism** is characterized by abnormal growth due to **GH** excess during childhood (ages 6–12), with growth significantly above average (2.1 to 2.7 m) [MSD manual, 2017]. The linear overgrowth is driven by the action of **IGF-1** while the epiphyseal growth plates remain open during childhood. Clinical signs include greater than normal height, a prominent forehead, and a protruding jaw. **Acromegaly** is the result of excessive **IGF-1** production after the closure of the epiphyseal plates. Clinical features include overgrowth of extremities, soft-tissue swelling, facial bone abnormalities (especially in the jaw), and an increased risk of cardiac diseases.

Deficiency: Deficiency of **GH** or dysfunction of its receptor leads to growth retardation or **dwarfism**. This occurs mainly via two mechanisms (Fig. 3). One is the failure of the liver to produce **IGF-1**, particularly in adults, where **IGF-1** alteration leads to reduced osteoblast activity, resulting in weakened bones that are more susceptible to pathologic fractures and osteoporosis [Ignatavicus & Workman, 2015]. The other mechanism involves the failure of **GH** production from the hypothalamic-pituitary axis, often due to structural lesions or trauma, a condition termed **idiopathic growth hormone deficiency (GHD)** [Molitch, 2006].

Parameter	Plant Hormones (PGRs)	Human Hormones (HGRs)
Source	Meristematic tissues, roots, leaves	Endocrine glands (pituitary, pancreas, etc.)
Types	Auxins, Gibberellins, Cytokinins, ABA, Ethylene.	GH, IGF-1, Somatostatin, Ghrelin
Transport Mechanism	Cell-to-cell diffusion, vascular tissues	Bloodstream
Mode of Action	Gene expression, signal transduction	Receptor-mediated pathways (MAPK, JAK/STAT)
Physiological Role	Growth, stress response, fruit ripening	Growth, metabolism, tissue regeneration
Disorders (if dysregulated)	Abnormal growth, poor yield	Gigantism, acromegaly, dwarfism

III. Conclusion

Growth regulators, whether in humans or plants, play a pivotal role in orchestrating developmental, physiological, and metabolic processes that are fundamental to life. In plants, **Plant Growth Regulators (PGRs)** such as **auxins, gibberellins, cytokinins, abscisic acid,** and **ethylene** similarly serve as chemical messengers, coordinating responses to internal genetic programs and external environmental cues. PGRs regulate seed germination, apical dominance, flowering, fruit ripening, and stress responses. Their actions, though mechanistically different from those in animals, demonstrate remarkable biochemical precision and adaptability, often involving signal transduction pathways, gene expression modulation, and secondary messengers.

In humans, **Growth Hormone (GH)** and its regulatory components such as **GHRH**, **Somatostatin**, **IGF-1**, and **Ghrelin** function through complex endocrine feedback loops, influencing linear growth, tissue regeneration, metabolism, and homeostasis. The precise control of **GH** synthesis and secretion highlights the critical balance required for normal development, as well as the pathological consequences of dysregulation, including **gigantism**, **acromegaly**, and **growth hormone deficiency**.

Future interdisciplinary studies in hormonal signaling may pave the way for innovations in precision agriculture and endocrine therapeutics, bridging gaps between botanical and biomedical sciences. The control of growth and development is deeply dependent on signaling molecules, their receptors, and tightly regulated feedback systems. Despite differences in molecular structure and physiological context, both **HGRs** and **PGRs** exemplify nature's use of chemical communication to sustain life, ensure reproduction, and adapt to changing environments. Comparative insights from both systems not only enrich our understanding of biology but also open avenues for innovations in medicine, agriculture, and biotechnology.

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