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Review

Gigantism in Theropods: A Study of *Giganotosaurus carolinii* and Its Ecological Impact

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Abstract: Gigantism in theropods represents one of the most intriguing phenomena in dinosaur evolution, showcasing extreme adaptations in body size and ecological roles. This literature review focuses on *Giganotosaurus carolinii*, one of the largest known theropods to have ever existed, to explore its unique aspects of gigantism and the subsequent ecological impacts. By analyzing features such as its skeletal morphology, comparative anatomy, and paleoenvironmental data, we assess the evolutionary pressures and biological constraints that shaped the gigantism observed in *Giganotosaurus*. We discover that the species exhibited a combination of physiological and ecological adaptations that allowed it to thrive as an apex predator in its Cretaceous environment. We will also further examine the implications of its size on prey dynamics, competition with other large theropods, and the overall ecosystem structure. Through a thorough, multidisciplinary approach, this research enhances our understanding of how gigantism influenced theropod behavior, interspecies interactions, and the broader paleoecological landscape.

Keywords: gigantism in theropods; *Giganotosaurus carolinii*; body size evolution; theropod morphology; ecological roles; apex predator; skeletal morphology; comparative anatomy; paleoenvironmental data; evolutionary pressures; biological constraints; physiological adaptations; ecological adaptations; cretaceous environment; prey dynamics; interspecies interactions; ecosystem structure; paleontological implications; theropod behavior; paleoecological landscape

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Gigantism in Theropods: A Study of *Giganotosaurus carolinii* and Its Ecological Impact

Giganotosaurus carolinii is considered one of the largest theropods to have existed on planet Earth, rivaling the sizes of creatures like *Tyrannosaurus rex* and *Spinosaurus aegyptiacus*, noted by Mazzetta* et al. (2004) and Therrien & Henderson (2007). With an estimated height of around 7 meters, a length spanning 12-13 meters, and a weight of 7,000-8,000 kilograms, *Giganotosaurus carolinii* presents a remarkable case for investigating the environmental and biological factors that drove theropods to achieve such immense sizes. Understanding these factors, such as climate and geography, can provide critical insights into the evolutionary pressures and ecological dynamics of their time. Additionally, another important aspect to consider is *Giganotosaurus carolinii*'s ecological niche and its impact on the surrounding environment. Some examples include its relationships with prey and competition against other theropods.

In our planet's history, environmental pressures have always been the root cause of a driving force that leads to drastic changes in morphology. Examples range from the large plants of the Carboniferous Period to the rise of mammals from the extinction of the dinosaurs. Perhaps through investigating the gigantism in theropods, we may gain an insight into the implications of these findings on both modern and future morphological developments in other organisms on planet Earth.

The purpose of this literature review is to delve into the various conditions and factors that could have contributed to the massive sizes of *Giganotosaurus carolinii* and other similar theropods. I will investigate features such as its skeletal morphology, comparative anatomy, and paleoenvironmental data. Then, I will examine *Giganotosaurus*'s ecological niche, such as its predator-prey relationships

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and competition against other theropods. Finally, I will conclude with all the factors, major and minor, that led to gigantism observed in *Giganotosaurus* and other similar theropods.

Morphology and Paleoenvironmental Pressures on *Giganotosaurus carolinii*

Giganotosaurus carolinii wielded a 1.8-meter elongated skull, serrated teeth, a powerful jaw, and strong hindlimbs to support movement. Morphological features like these provide an essential insight into the characteristics that enabled *Giganotosaurus* to be the apex predator of its Late Cretaceous ecosystem near what is now Patagonia. Based on existing fossil evidence, these environments likely included a mix of river floodplains, wetlands, and forested areas that supported diverse dinosaur communities. Similarly, another crucial aspect is the paleoenvironment of *Giganotosaurus*, as it also determines the occurrence of morphological change.

An investigation conducted by Corria & Currie (2003) described the skull of *Giganotosaurus* in detail, noting its length, robust construction, and features such as a wide rostrum. The study also highlighted specific cranial features, such as the presence of a deep postorbital fossa and the configuration of the nasal and lacrimal bones. Postcranial, there existed features like the robust and elongated cervical vertebrae, the large and blade-like neural spines, and the structure of the pelvis and limbs (Coria & Salgado, 1995). An observed, unique characteristic of *Giganotosaurus* was its prominent ridge located on the lateral surface of the nasal bone, a feature not seen in other carcharodontosaurids. Many of these features aid in hunting prey, protection against threats, and displays of dominance, and thus are supplemental to a large, carnivorous theropod like *Giganotosaurus*. Additionally, the evolution of large body size occurred independently in different theropod lineages, with *Giganotosaurus* representing an example of gigantism within the Carcharodontosauridae family. Hence, it is likely that *Giganotosaurus* and other members of its family experienced convergent evolution with families such as the *Tyrannosauridae* family towards gigantism, suggesting that environmental pressures were a considerable factor.

Another study by Novas et al. (2013) analyzed the evolutionary trends of theropod dinosaurs. It was asserted that body size evolution in theropods involved various trade-offs between predation, competition, and resource availability. Larger body size might offer advantages such as greater predatory capability or competitive dominance, but it also comes with costs, such as increased energy demands and metabolic processes. This trend is observed throughout all of Earth's natural history, including in modern organisms (Alexander, 2005). It is important to note that in the case of *Giganotosaurus*, it is likely that the advantages significantly outweigh the disadvantages, as it occupied its position as the top predator of its ecosystem for the entirety of its existence.

We must now compare *Giganotosaurus* to other large theropods like *Tyrannosaurus rex* and *Spinosaurus aegyptiacus* to understand the reason behind gigantism in these organisms. A key commonality between all three of these carnivorous theropods is the period in which they were present: The Cretaceous. Though many changes to an environment can occur within the time in between the existence of *T. rex*, *Spinosaurus*, and *Giganotosaurus*, due to their existence in the same period, the fauna of the surrounding environment likely had similar effects on the growth and development of them.

We must also investigate other environmental factors such as atmospheric conditions to determine the factors leading to gigantism in theropods. Two studies can aid us regarding this aspect. One study was conducted by Hong & Lee (2012), in which Cretaceous CO_2 levels were estimated. The carbon dioxide levels for each time were as follows: Early Cretaceous: ~1,200-1,800 ppm, Mid-Cretaceous: ~2,000-2,500 ppm, Late Cretaceous: ~1,000-1,500 ppm. The estimates were derived using isotopic analysis of carbonate minerals and organic matter, serving as proxies for ancient atmospheric CO_2 levels. Comparing these results to the modern-day CO_2 concentration of 421.41 ppm (Current CO_2 levels are approximately 421.41 ppm, NOAA, 2024), they are significantly higher, providing another reason behind gigantism. As CO_2 levels were much higher, this ancient environment would have greatly supported the growth and development of vegetation, allowing for an abundance of plant life. This would have provided a stable food source for herbivorous dinosaurs, which in turn supported large carnivorous dinosaurs like *Giganotosaurus*.

The second study by Saltzman & Barron (1982) examined the isotopic composition of *Inoceramus* shells. The results indicated that deep ocean waters were relatively warm during the Late Cretaceous compared to present-day deep ocean temperatures, likely linked to the higher levels of atmospheric CO_2 and overall warmer global climate during that period, as observed by Hong & Lee (2012). As a result of these two studies, we can determine that the higher CO_2 levels of the Mesozoic, especially the Cretaceous, would have supported an abundance of plant life, herbivorous dinosaurs, and large carnivorous theropods.

Therefore, it is reasonable to conclude that *Giganotosaurus* and other similar theropods such as *Tyrannosaurus rex* and *Spinosaurus aegyptiacus* were able to attain their immense size due to various paleoenvironmental conditions such as high CO_2 levels, which allowed for an abundance of plant life and herbivorous dinosaurs, as well as a means of increased predatory capability.

Ecological Impact of *Giganotosaurus carolinii*

Giganotosaurus carolinii likely served numerous ecological roles, ensuring that its Patagonian environment remained stable and functional. Perhaps it might have served as a keystone species, in which its entire surrounding ecosystem would have collapsed upon itself without the presence of *Giganotosaurus*. Here, we delve into these possible roles and discuss their relevance to our review.

Giganotosaurus was likely a hypercarnivore, preying on large herbivorous dinosaurs. The large body size and robust dentition of *Giganotosaurus* suggested it was efficient in taking down substantial prey, similar to other large theropods like *Tyrannosaurus rex*. Additionally, the extensive presence of *Giganotosaurus* would have had a major influence on the distribution and behavior of large herbivores, shaping the dynamics of Late Cretaceous ecosystems in Patagonia.

Additionally, larger theropods with more upright postures and longer limbs were likely capable of faster and more efficient running. As a result, being of massive size would have increased *Giganotosaurus*' ability to hunt down larger prey such as sauropods, ceratopsians, and hadrosaurs. Some extensive uses included hunting and possibly herding or chasing prey more effectively.

It is also important to note the metabolic demands of large theropods like *Giganotosaurus*. The massive body size of *Giganotosaurus* and similar theropods meant they had high energy demands, which would have influenced their hunting strategies and prey preferences. They likely specialized in preying on large herbivores to obtain the greatest available energy, and their size allowed them to hunt and consume significant quantities of food. We must also address the concept of interspecific competition among large carnivorous theropods that occupied the same region. To meet their high metabolic demands, these creatures might have engaged in niche partitioning to encounter minimal competition.

As one of the largest known theropods, *Giganotosaurus*'s role in the food web would have been significant. Its size and predatory capabilities allowed it to exert top-down control on herbivorous dinosaur populations, likely influencing their behavior, distribution, and population dynamics. *Giganotosaurus* would also probably have had direct impacts on the herbivorous dinosaurs in its environment. Large herbivores, such as sauropods, would have had to develop various defensive adaptations, such as herding behaviors, increased vigilance, and physical defenses to minimize predation risks. The constant threat from *Giganotosaurus* would drive evolutionary changes in these prey species, creating a relationship of coevolution between predator and prey.

An insightful study conducted by Sander et al. (2011) analyzed gigantism in large herbivorous dinosaurs, specifically the sauropods. The scientists cited increased foraging efficiency and reduced predation risk as major factors behind this observed trend. For instance, sauropods would have much greater access to vegetation compared to smaller dinosaurs closer to the forest floor. Consequent developments through evolution led sauropods to have hollow bones, large nasal passages, and efficient respiratory systems to support their large body sizes. This further proves the coevolution between large carnivorous theropod dinosaurs and their immense prey. In addition, these findings determine that the immense size of *Giganotosaurus* and other similar theropods was a means of ecological balance and preventing excess herbivory.

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Giganotosaurus and other larger theropods like *Tyrannosaurus rex* might have also scavenged, influencing the availability of carrion and affecting other scavenger species within their respective ecosystems. This behavior would have contributed to nutrient cycling and the overall dynamics of the ecosystem. Furthermore, other scavengers, such as smaller theropods, mammals, or even smaller reptiles, would compete with *Giganotosaurus* for the same carrion. This competition could influence the abundance, distribution, and feeding distributions of these scavenger species. For example, smaller scavengers might have avoided areas frequented by *Giganotosaurus* or fed at different times to reduce competition, thus bringing to light another form of niche partitioning caused by large carnivorous theropods.

Therefore, it is probable that *Giganotosaurus* and other similar theropods influenced the population and behavioral dynamics of both prey and competing theropods. They also engaged in coevolution with their prey, especially observed in sauropods. Additionally, these dinosaurs might have caused niche partitioning in competing carnivores and scavengers.

Conclusions

Limitations on Existing Research

Though several existing studies were able to help us in our review of gigantism in theropods, specifically carnivorous ones like *Giganotosaurus carolinii*, there is still much more research to be done to fully understand the environmental pressures that led to their massive size. Most of our current knowledge is based on speculation and parallels to modern organisms, as well as fossils from excavation sites. One significant limitation is the incomplete nature of the fossil record. Many fossilized remains are fragmentary, making it challenging to reconstruct the full anatomy and physiology of these enormous predators. Additionally, the scarcity of soft tissue preservation hinders our ability to make definitive conclusions about their metabolism, growth rates, and thermoregulatory mechanisms. Without these details, it is difficult to determine the precise biological factors that contributed to their gigantism. Furthermore, the paleoenvironmental conditions during the Mesozoic era are not fully understood. While we can infer certain climatic and ecological aspects from sedimentary records and isotopic analyses, the dynamic and complex nature of ancient ecosystems means that many factors influencing theropod gigantism remain speculative. For instance, fluctuations in prey availability, competition with other large predators, and changes in vegetation could have played crucial roles but are challenging to quantify with current evidence. Therefore, there are numerous limitations to our understanding of gigantism in theropods and their ecological impacts.

Takeaway

Based on current evidence, we can reasonably conclude that *Giganotosaurus carolinii* and other large carnivorous theropods likely attained their immense size due to various paleoenvironmental conditions such as increased predatory capability. Furthermore, an incredibly high concentration of CO_2 allowed for an abundance of plant life and large herbivorous dinosaurs, thus favoring larger carnivorous theropods, as they would be evolutionarily better-equipped to hunt these larger herbivores compared to smaller carnivores. This created a relationship of coevolution between predator and prey, as the increased size of prey led to an increased size of predators. Additionally, these large carnivorous theropods likely engaged in complex predator-prey and inter-predator dynamics, influencing both the behavior of prey and competing carnivores. Niche differentiation or specialization in hunting strategies, as well as scavenging, might have occurred to minimize direct competition for resources.

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