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Carcinisation Beyond Earth: Could Alien Life Take the Form of Crabs?

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Abstract
On Earth, crabs have appeared independently across different crustacean groups, highlighting their evolutionary success in a wide range of environments. This repeated emergence suggests that the crab-like body plan offers significant advantages. Could this recurring evolutionary pattern be universal, with alien worlds harbouring their own crabs adapted to extraterrestrial conditions?

Keywords: *Speculative evolution*; *Biology; Astrobiology; Space; Evolution; Aliens; Crabs*

Introduction
Crabs are a recurring theme in evolution, with crustaceans repeatedly evolving a crab-like form (Figures 1 & 2) through a process known as carcinisation. First described by zoologist Lancelot Borradaile in 1916, this process involves the reduction of the abdomen and broadening of the cephalothorax (Figure 3), resulting in a favoured body plan [1]. Crabs belong to two decapod infraorders, Brachyura ('true' crabs) and Anomura ('false' crabs), both within the Meiura clade. They share a crab-like body plan but differ in leg structure and antennae. Brachyura have four pairs of walking legs, while Anomura have three, with longer antennae [2].

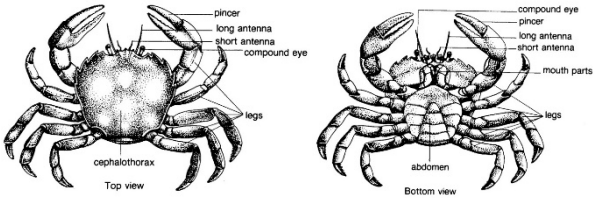

Figure 1 – Diagram showing the anatomy of a crab, with features labelled [3].

Carcinisation has significantly influenced Anomura, with several species, including king crabs as shown in Figure 2, independently developing crab-like features through convergent evolution, despite their ancestors possessing non-crab like features [1].

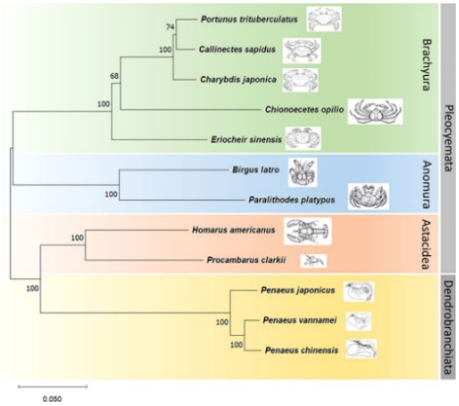

Figure 2 – Phylogenetic tree of 12 Decapoda species based on ANK2 protein fragments, showing evolutionary relationships. Anomura species, including *Birgus latro* (coconut crab) and *Paralithodes platypus* (king crab), are outside the Brachyura infraorder despite their crab-like appearance [4].

The repeated emergence of crab-like forms on Earth suggests that carcinisation offers evolutionary advantages. This raises the question: could similar processes occur on other planets with environments that favour such adaptations?

Adaptive Advantages of Crab-Like Morphology
Crabs have successfully colonised marine, semi-terrestrial and terrestrial environments, including deserts [5]. This adaptability is supported by key traits such as specialised gills and branchial chambers for gas exchange in both air and water [6] and a chitin exoskeleton that provides support and protection

and prevents desiccation, while being more material-efficient than an endoskeleton [7, 8]. Sensory adaptations such as antennae aid in detecting food, while chelipeds, used for defence and prey capture, further enable survival [7]. Terrestrial species have developed strategies to prevent water loss, including impermeable exoskeletons, behavioural tactics, such as seeking shelter in humid areas, and osmoregulatory systems to manage fluctuating salinity [6]. These traits, combined with improved locomotion, such as a bent pleon and reduced uropods, allow crabs to navigate diverse habitats, enhancing survival in both aquatic and terrestrial environments [1].

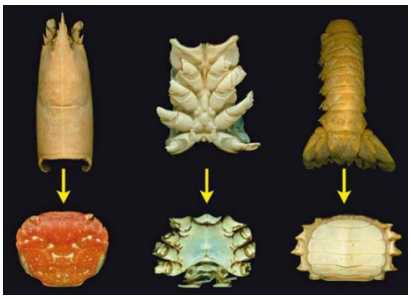

Figure 3 – The changes that occur during carcinisation. (Left) The flattening and shortening of the carapace; (middle) The widening of the sternum; (right) The reduction and folding of the pleon [9].

The Potential for Alien Crabs: Convergent Evolution Beyond Earth

The adaptability of Earth crabs supports the possibility of alien crabs evolving in similar environments. Yeti crabs, for example, thrive in hydrothermal vents reaching 383 °C [10], using specialised structures for food acquisition and thermal regulation (Figure 4) [11]. Yeti crabs adapt to hydrothermal vents with dense, hair-like setae that provide a surface for farming chemosynthetic bacteria, specialised chelipeds for gathering microbes and reduced, often vestigial eyes to conserve energy in the deep-sea darkness [12]. Hydrothermal vents are speculated to exist on moons including Enceladus and ocean exoplanets such as GJ 1214b [13, 14, 15], potentially supporting similar life through chemosynthesis.

Fiddler crabs adapt to desert heat by burrowing, creating a cooler microclimate to conserve moisture and avoid predators [16]. Similarly, coconut crabs, capable of climbing trees (Figure 5), demonstrate adaptability to diverse terrestrial environments. On a super-Earth like Gliese 12 b [17], where gravity and

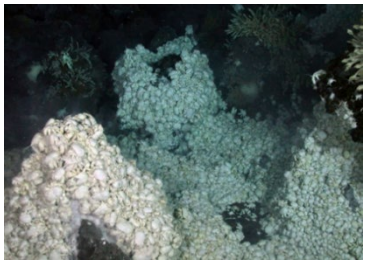

Figure 4 – Yeti crabs living around hydrothermal vents in the Southern Ocean [18].

Figure 5 – A coconut crab, the largest terrestrial decapod, climbing a tree [19].

atmospheric composition may differ, crabs could develop traits to thrive. The presence of rocky deserts or forests could drive adaptations similar to Earth's fiddler and coconut crabs, enabling survival in extreme environments.

The adaptability of crabs on Earth, demonstrated by repeated carcinisation under similar pressures [2], suggests the potential for extraterrestrial crabs. Crabs thrive in extreme habitats and show resilience to harsh conditions. Comparable selective pressures, such as predation, resource competition and environmental extremes, could drive the evolution of crab-like forms on other worlds. However, Earth's relatively stable climate allows for gradual adaptation. Planets with less stable conditions may require rapid adaptability instead, potentially limiting carcinisation.

Conclusion

The repeated evolution of crab-like forms on Earth through carcinisation highlights the success of this body plan in diverse environments. From hydrothermal vents to deserts and forests, crabs have adapted to extreme conditions. This adaptability alongside parallel evolution suggests that similar processes could occur on other planets with environments that favour such adaptations. While speculative, the prospect of alien crabs is supported by both the adaptability of Earth's crabs and the potential for analogous habitats on exoplanets and moons.

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