New Insights on the Evolution of the Sweet Taste Receptor of Primates Adapted to Harsh Environments

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Simple Summary: A sense of taste is vital to an animal’s fitness. It enables animals to select and ingest beneficial foods and avoid harmful substances in their daily lives. There have been relatively few studies regarding the evolution of the taste receptor gene for sweetness, particularly in regard to endemic Bornean primates. We constructed TAS1R2 gene phylogenies for 20 anthropoid primate species using four different methods as well as established the phylogenetic time divergence. The phylogenetic analysis successfully separated the primates into their taxonomic groups and as per their dietary preferences. Of note, the estimated time of divergence for the primate speciation pattern in this study was more recent than the previously published estimates. This difference may have been due to environmental changes, such as food scarcity and climate change, during the late Miocene epoch, which likely forced primates to adapt their dietary preferences. These findings establish a foundation for further investigations.

Abstract: Taste perception is an essential function that provides valuable dietary and sensory information, which is crucial for the survival of animals. Studies into the evolution of the sweet taste receptor gene (TAS1R2) are scarce, especially for Bornean endemic primates such as Nasalis larvatus (proboscis monkey), Pongo pygmaeus (Bornean orangutan), and Hylobates muelleri (Muller’s Bornean gibbon). Primates are the perfect taxa to study as they are diverse dietary feeders, comprising specialist folivores, frugivores, gummivores, herbivores, and omnivores. We constructed phylogenetic trees of the TAS1R2 gene for 20 species of anthropoid primates using four different methods (neighbor-joining, maximum parsimony, maximum-likelihood, and Bayesian) and also established the time divergence of the phylogeny. The phylogeny successfully separated the primates into their taxonomic groups as well as by their dietary preferences. Of note, the reviewed time of divergence estimation for the primate speciation pattern in this study was more recent than the previously published estimates. It is believed that this difference may be due to environmental changes, such as food scarcity and climate...
change, during the late Miocene epoch, which forced primates to change their dietary preferences. These findings provide a starting point for further investigation.

**Keywords:** primate; phylogenetic; sweet taste receptor gene; diet preference; divergence date; late Miocene

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1. Introduction

Taste is a vital component of an animal’s fitness. It facilitates animals in making decisions about the ingestion of beneficial foods and avoiding harmful substances in their daily life. Taste evolved to ensure animals choose the appropriate foods for their survival. Taste sensations can be divided into five basic elements: sweet, umami, bitter, salty, and sour [1,2]. Bitter and sour tastes usually warn against hazardous substances, whereas sweet and umami tastes indicate foods that are rich in carbohydrates and proteins, respectively [3]. Salty tastes indicate foods that are rich in sodium and other minerals that are required by animals for optimum biological function.

Sour and salty tastes are conferred by taste receptor cells, which use ion channels, whereas sweet, umami, and bitter tastes are conferred by G protein-coupled receptors (GPCRs) [2,3]. GPCRs comprise two families: taste 1 receptors (TAS1Rs) and taste 2 receptors (TAS2Rs), which function as sweet or umami and bitter taste receptors, respectively [4]. The TAS1R gene has a smaller gene repertoire compared with the TAS2R gene and comprises three genes in most mammals, namely, TAS1R1, TAS1R2, and TAS1R3 [5]. These receptors only function as heterodimers, with TAS1R3 an obligate partner of both the umami and sweet receptors. The dimer TAS1R1 + TAS1R3 acts as the main receptor for umami, whereas TAS1R2 + TAS1R3 respond to a variety of natural and artificial sweet ligands [6]. Thus, we can conclude that TAS1R2 is probably the sole sweet-specific taste receptor gene.

The evolution of TAS1R has been less well-studied and characterized compared with the evolution of TAS2R because the sweet and umami taste genes are believed to be conserved among species as these genes are necessary for nutrient uptake [7]. However, recently, several studies have demonstrated that the TAS1R genes undergo major mutations, revealing new insights regarding the evolution and function of the gene. For example, TAS1R1 is pseudogenized in the giant panda [8], TAS1R2 is inactivated in the cat family Felidae [9], and TAS1R2 is pseudogenized in vampire bats [5]. Consequently, the TAS1R gene repertoire is not conserved as predicted. To better understand the evolutionary dynamics of the TAS1R2 gene, examining species that are closely related to humans that have diverse dietary preferences is necessary.

To obtain a deeper understanding of the phylogenetic relationship between primates’ sweet taste perception, a study of the molecular phylogenetics of the TAS1R2 gene in primates was conducted. We chose primates because their diets are hugely diverse and include shoots, leaves, plants, fruits, gums, nectars, insects, invertebrates, small mammals, and amphibians (Table 1) [10–15]. For simplicity, we classified primates into four main dietary groups, namely, frugivores, folivores, omnivores, and gummivores, to discuss the possible environmental factors and diet preferences that have influenced the evolution of TAS1R2.

**Table 1.** Food preferences of primates found mainly in Southeast Asia and Borneo.

| Dietary Groups | Primate | Preferred Diet |
|---------------|---------|----------------|
| Gummivore     | Marmosets | Gum, sap, latex, and resin |
| Folivore      | Langurs, snub-nosed monkeys, proboscis monkeys | Shoots, young leaves, and unripe fruits |
| Omnivore      | Macaques, tarsiers, slow lorises, humans, baboons, Patas monkeys, gorillas, chimpanzees | Flexible diets including fruits, leaves, insects, bird eggs, small mammals, and amphibians |
| Frugivore     | Squirrel monkeys, siamangs, gibbons, orangutans | Ripe fleshy fruits and mature leaves |