

REDUCTIONIST VS. FOLK TAXONOMIES IN PLANETARY SCIENCE. P. T. Metzger¹, W. M. Grundy², M. V. Sykes³, S. A. Stern⁴, J. F. Bell III⁵, C. E. Detelich⁶, K. D. Runyon⁷, and M. E. Summers⁸. ¹Florida Space Institute, University of Central Florida, 12354 Research Parkway, Partnership 1 Building, Suite 214, Orlando, FL 32826-0650. philip.metzger@ucf.edu. ²Lowell Observatory, 1400 W. Mars Hill Rd., Flagstaff, AZ 86001. ³Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ, 85719, USA. ⁴Southwest Research Institute, 1050 Walnut St, Suite 300, Boulder, CO 80302, USA. ⁵Arizona State University, School of Earth and Space Exploration, Box 876004, Tempe, AZ 85287-6004. ⁶Department of Geological Sciences, University of Alaska Anchorage, 311 Providence Drive, CPSB 101, Anchorage, Alaska, 99508. ⁷Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723. ⁸George Mason University, 4400 University Drive, Fairfax, VA 22030.

Introduction: In healthy science, concepts like *planet* evolve to align with the categories that scientists need for reductionist explanations of nature [1,2]. E.g., whales were once fish, but Linnaeus argued phylogeny over environment so they should be mammals. Folk taxonomies evolve in parallel with scientific ones because the public wants concepts that align with human-centric concerns. Science communication tries to convince the public that folk taxonomies are not suitable for understanding nature. Unfortunately, folk taxonomies can leak back into science [3], undermining progress. This happened with the concept of a planet.

The Copernican Planet Concept: Copernican scientists kept the Moon as one of the planets. When Galileo saw mountains on the Moon and evidence of earthshine reflecting off the Moon, he argued that the Earth and the Moon share complex geophysics, so by induction all the planets were recognized as “other Earths” with complex geology including potential for life [4-7]. This was reductionist by eliminating Aristotelian celestial physics in favor of universal geophysics, relying on comparative planetology between the two most observable planets, the Earth and the Moon. The taxonomy that kept the Moon as a planet was operative in the induction [4]. The moons of Jupiter, Saturn, Uranus, etc., were likewise classified as planets [8-11] and kept as such for the next 300 years [12,13]. Kepler added dynamical subcategories: *primary planets* are planets that orbit the Sun directly while *secondary planets* (moons) are planets that orbit another planet [14]. Astronomers recognized that primaries and secondaries formed from the same materials by the same processes as each other and that dynamical states can change [15]. Triton is a modern example.

The Folk Planet Concept: The question arises then, where did the idea come from that planets must directly orbit the Sun? The public still held to geocentrism into the 1800s [16]. When they switched, science education was inadequate to ensure the public would adopt the entire package including the taxonomy. The public naturally developed its own taxonomy with human-centric themes that it deeply valued from geocentrism and astrology. The public’s main sources of information were the popular almanacs [16]. In the

1800s they taught a wide variety of *planet* concepts falling into three main groups: (1) phenomenological geocentrism (2) hybridized helio/geocentrism; and (3) simplified heliocentrism. The third emerged as the most popular by the mid-1800s. All three communicated a view of the Solar System compatible with theological and astrological teleology such that the planets *serve* the people of Earth even though they no longer *orbit* the Earth. Most secondary planets and asteroids could not fit those themes so were omitted from the new *planet* concept, and eventually Earth’s Moon was eliminated for consistency. Secondary education textbooks and popular books began switching from the Copernican taxonomy to this new folk taxonomy beginning in 1857. Science texts still taught the reductionist Copernican taxonomy into the 1920s.

The Great Depression of Planetary Science: As shown in Fig. 1, publications about astronomy, planets, and satellites grew exponentially until 1894 when they entered a 60 year stagnation. Publications on planets and satellites entered sharp decline ca. 1910 for 45 years. This *Great Depression of Planetary Science* (GDPS) indicates a loss of interest in planets apparently due to technological limitations that failed to produce new geophysical data to drive advances. It was during the GDPS that astronomy texts stopped teaching the reductionist Copernican taxonomy, switching to the folk taxonomy that the public had developed.

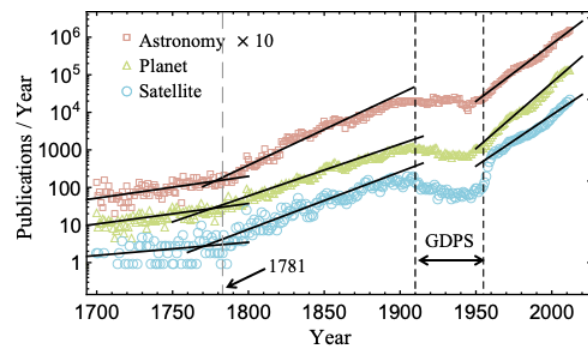


Figure 1. Exponential growth and the GDPS

Publications on *satellites* suddenly exploded ca. 1955 marking the end of the GDPS. This timing

correlates with the foundation of civilian space agencies and their planning and operation of spacecraft missions which brought in a new wealth of geophysical data about planets including the satellites.

Rediscovery of the Reductionist Taxonomy:

Immediately, the new planetary science community began calling satellites “planets” again in professional publications. The literature shows this usage in the context of geophysics including atmospheres, mantle and core processes, oceans, surface geology, magnetospheres, biochemistry, potential for life, etc. This taxonomical re-emphasis on geophysics affected not just moons but also asteroids. From the early 1800s, scientists had considered asteroids to be planets [17]. Kuiper [18,19] argued that only those asteroids which were gravitationally rounded during formation are true planets. Within ten years as geophysical data on asteroids poured in, scientists stopped considering asteroids to be planets (Ceres being an exception). While this was motivated by reductionism, it coincidentally aligned with the public’s folk taxonomy because it made the view of planets more orderly.

Presentist Fallacy Supporting the Folk Taxonomy: Although planetary scientists were reviving reductionist taxonomy, the astronomical community fell into the presentist fallacy [20], inventing an origin story for the folk taxonomy different than its true origin. They read into history two events that never actually occurred: (1) the idea that the Copernican Revolution made moons into non-planets [21], and (2) the idea that scientists reclassified asteroids as non-planets as early as 1851 when there were only about 15 known [21,22]. Both claims are contrary to the published literature. If those two events had occurred, they would have been examples of the community doing bad taxonomy since there was no reductionist theory developing during those time periods to motivate such taxonomical choices. (In fact, the theory of those times motivated the opposite taxonomical choices [17].) Therefore, those who currently believe the presentist revision are left with the false notion that taxonomy has *never* held a functional role in planetary science, so taxonomical choices may as well accommodate culture.

Geophysical Complexity as the Essence of Planethood: The modern version of the Geophysical Planet Definition (GPD) appeared in two stages. First, Stern [23] and others argued beginning in the 1990s that gravitational rounding be the dividing line between planets and small bodies, so Ceres and many KBOs are planets. Sykes noted that gravitational rounding is when geophysical complexity “turns on” [24]. This version of the GPD was proposed by the IAU’s planet definition committee at the 2006 IAU assembly (but astronomers voted it down in favor of the folk taxonomy). Second,

Runyon et al. [25] noted that planetary science usage often includes moons as planets and that reductionism requires secondaries be included in the *planet* taxon. Dynamical status – primaries vs satellites – was restored to the Keplerian position as a lower tier in the taxonomy.

Taxonomical Usefulness: Some astronomers have claimed that the *planet* concept is too broad to be useful in science, anyway. That is only true if one is looking through the lens of the folk taxonomy. Looking through the lens of the Copernican taxonomy, the *planet* concept is one of the most important conceptual advancements in science: the emergence of geophysical, chemical, and biological complexity in the cosmos happens uniquely in planets. This is the same essential insight Galileo had when he saw lunar mountains, compared them to Earth’s, and identified the key feature of the *planet* taxon. This insight is muddled or lost in the folk taxonomy because it splits the taxon along dynamical boundaries that do not align with the processes of geophysical complexity. It would be the same as removing whales from the mammal taxon because they swim in the ocean, thus muddling the reductionist insights of mammalian evolution. The point of science is to elucidate reductionist insight. It is vital to reject the 19th century folk taxonomy that was a compromise of heliocentrism with teleology and to restore the scientific taxonomy that came from the Copernican Revolution.

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