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**SOCIALITY IN E. O. WILSON'S *GENESIS*:
EXPANDING THE PAST, IMAGINING THE FUTURE.**

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**Sociality in E. O. Wilson's *Genesis*:
Expanding the Past, Imagining the Future.**

Woodrow W. Denham, Ph. D.

Abstract. In this article, I critique Edward O. Wilson's (2019) *Genesis: The Deep Origin of Societies* from a perspective provided by David Christian's (2016) *Big History*. *Genesis* is a slender, narrowly focused recapitulation and summation of Wilson's lifelong research on altruism, eusociality, the biological bases of kinship, and related aspects of sociality among insects and humans. Wilson considers it to be among the most important of his 35+ published books, one of which created the controversial discipline of sociobiology and two of which won Pulitzer Prizes. *Big History* is Christian's recent attempt to graphically depict the history of the universe in a massive, sprawling, well documented volume that opens with the Big Bang and terminates now, about 13.8 billion years later.

I take four disparate approaches to enhancing the strengths of Wilson's and Christian's important books. Part 1. *Expanding the past* examines 1. contextual data for numerous transitions in sociality in the distant past, and 2. ethnographic data pertaining to kinship and warfare in Australian Aboriginal hunter-gatherer societies in the recent past. Part 2. *Imagining the future* speculates about 1. predictive applications of sociality research as we approach another mass extinction in the near future, and 2. social research concerning globular star clusters in the remote future. Small scale case studies feature, among other things, two species of colonial microorganisms, the Alyawarra speaking people of Central Australia, and social insects as a background for all else. Although Wilson's extensive quantitative research deals mainly with kinship and related topics among ants, bees, wasps and termites, it is not limited by time, space or species.

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Introduction.

At the age of ninety years, biologist E. O. Wilson is approaching the end of a long, productive and controversial career as the world's leading expert on ants. His specialty areas include the biological bases of kinship and related social behaviors among the social insects (ants, bees, wasps and termites), and principal topics include eusociality, kin selection, altruism and superorganisms. His 1975 book entitled *Sociobiology: The New Synthesis* established the discipline of sociobiology that became a major thread in 20th century evolutionary biology. However, his focus on the genetics of kinship and the biological bases of social behavior among all animals including humans profoundly offended many anthropologists who have rejected – and largely ignored - his work for almost 45 years.

Unlike many of my colleagues in anthropology, I have uniformly admired Wilson's work and often have cited it favorably in my own publications. I continue that tradition in this positive response to *Genesis: The Deep Origin of Societies* (Wilson 2019). Of more than 35 books that he has published, including two Pulitzer Prize winners, Wilson says that *Genesis* is “one of the most important books [he has] written” (Dreyfus 2019).

Here I neither review the book in great detail nor engage in controversy about it. Rather, while aiming to enhance the timeline of life on Earth in Christian's *Big History*, I take four disparate approaches to building on the many strengths of Wilson's *Genesis*. **Part 1. Expanding the past** examines 1. contextual data for historical transitions in sociality, and 2. ethnographic data on kinship and warfare in hunter-gatherer societies. **Part 2. Imagining the future** speculates about 1. predictive applications of sociality research, and 2. social research concerning nearby globular star clusters.

Metaphorically speaking, Christian's book is the "stage", Wilson's is the "play" and a formidable cast of characters¹ brings the story to life. I focus primarily on the play and the on-stage actors, but I say a lot about the stage as well.

Concerning contextual data, *Genesis* is a succinct summary of much of Wilson's work on sociobiology. It is written for general readers as well as for specialists, but Wilson omits a lot of data that readers need to evaluate the book critically. An applicable quote attributed to Albert Einstein² is a paraphrase of Occam's Razor: "Everything should be made as simple as possible, but no simpler." Evolution is not a lockstep, one-size-fits-all process, but as Wilson (2019:111) notes it is a complex mosaic at all levels in the taxonomy. Since Wilson kept *Genesis* slender – perhaps too slender - I introduce some tabular data from Christian's *Big History* concerning historical timelines and transitions in sociality. I then edit those data considerably to suit my own purposes and include several photographs to make important points visually.

Concerning ethnographic data, Wilson argues that adult mortality due to warfare was high in hunter-gatherer societies and cites flawed data from three Australian Aboriginal societies to bolster his position. I challenge those data and argue that one and probably more Australian Aboriginal societies achieved Wilson's "superorganism" status before the European invasion.

Concerning predictions, Hamilton's (1964) mathematics on kin selection and altruism helped Wilson formulate *Sociobiology* as a book and as an intellectual movement. Now Wilson (2019:100-101) has turned away from Hamilton, arguing that Hamilton's work contains three fatal flaws, one of which is that it is "logically incapable of making any prediction about any situation". The charge and ensuing largely mathematical controversy erupted first in 2010 (Nowak et al 2010, Abbott et al. 2011, Nowak et al. 2011, Pennisi 2011) and are serious.

Regardless of the outcome they offer strong evidence that Wilson tests his own hypotheses and rejects them when he discovers problems. The fact that Wilson (2019) defends his 2010 recantation nine years later suggests that he and his mathematician colleagues who evaluated Hamilton's early work consider themselves to be standing on solid ground. Since I am not qualified to evaluate the intricacies of that controversy, I am willing to give Wilson's team the benefit of any remaining doubts. But I am less interested in the controversy itself than in the fact that *Genesis* does not predict anything either. In what sense should a theory of sociality offer predictions? Given the mass extinction facing us now, about which Wilson (2002) has written eloquently, I take this opportunity to extrapolate from looking "backward and downward" at the evolutionary past of ants to looking "forward and upward" toward the evolutionary future of humans.

¹ Major on-stage actors include E. O. Wilson (b. 1929), William Hamilton (b. 1936), Carl Woese (b. 1928), Carl Sagan (b. 1934), Lynn (Sagan) Margulis (b. 1938) and Isaac Asimov (b. 1920), while off-stage actors in the role of *éminence grise* include Charles Darwin (b. 1809), Francis Crick (b. 1916), Rosalind Franklin (b. 1920) and James Watson (b. 1929).

² Possibly paraphrased from [Einstein's] remarks in "On the Method of Theoretical Physics", Herbert Spencer Lecture, Oxford (10 June 1933), *Philosophy of Science* 1(2):165 (*Wikiquotes*, Simplicity 8-14-2019 <https://en.wikiquote.org/wiki/Simplicity>).

Next I make a large leap. I suggest that sociality glossed broadly as “group living” presupposes neither consciousness nor choice but pertains minimally to processes of dispersal and patterns of dispersion (Armstrong 1977). As such, it applies equally well to the behavior of animals, plants and bacteria, and to the bonds that hold these groups together including genetics, physiology, chemistry, symbolism and kinship. I suggest that a suitably broad definition of sociality must include gravity in a literal sense and focus my attention on the M13 globular star cluster that is visible with binoculars in the night sky from the northern hemisphere. I suggest that restricting the applicability of sociality to living entities is an extreme example of speciesism; i.e., discrimination based on membership in an alien species or genus or some other taxonomic category (Ryder 1971, Singer 1975, *Wikipedia* 2019 Speciesism).

Part 1. Expanding the Past.

1.1. Historical transitions in sociality.

Part 1 deals primarily with relationships between Tables 1 and 2 as reflected in Table 3³.

Wilson’s (2019: 29-40) *Genesis* Chapter 2 introduces a variation on a generally accepted list of 6 major phase transitions, in chronological order, in the history of life on Earth (Maynard Smith and Szathmary 1999). The items in Table 1 mark the origin of each new phase. Perhaps it is not coincidental that the length and content of the list is reminiscent of the *Old Testament Book of Genesis*.

- Life
- Eukaryotic cells (alternate spelling: eucaryotic)
- Sexual reproduction
- Multicellular organisms
- Societies
- Language

Table 1. Historical sequence of major transitions in life on Earth.

Wilson’s (2019:61-70) Chapter 5 focuses on the concept of sociality, which minimally means “group living” (Kerth 2008:737) encompassing globular clusters to human societies, but beyond that may mean the degree to which individuals in an animal population tend to associate in social groups and form cooperative societies (*Wikipedia* 2019. Sociality). It rests, directly or indirectly, on whatever it is that bonds the members of a society together - genetics, physiology, chemistry, symbolism, kinship, even gravity. Thus, it is a complex measure of social organization within a community and can be computed for life on Earth with Hamilton’s Rule (see below) or related gene-based procedures.

³ This is a multidisciplinary article in which you may encounter technical terms with which you are not familiar. If so, please use the web as your glossary where virtually all of the terms are defined.

Eusociality, meaning “true sociality”, is a major topic in *Genesis* and has been defined repeatedly over the last half-century, with more or less detail and increasing precision, by Wilson (1975:398; 2019:72-78; Hölldobler and Wilson 2009:8-9) and many others. Principle features of true eusociality include the presence of all traits in Table 2 in co-residing social groups. A defining feature of it is the presence of a biologically based caste system in which some categories of adults do not reproduce but engage in various forms of altruistic behavior that benefit other members of the group to varying degrees depending upon the closeness of their kin relationships. Co-residing social groups with some but not all traits in Table 2 can be characterized as having lower levels of sociality.

- Parental investment
- Cohabitation of all adults and young
- Cooperative care of young
- Reproductive division of labor
- Caste system
- Overlapping adult generations

Table 2. Sociality scale

While eusociality incorporates all items in Table 2, it nevertheless comes in various grades or levels. Extreme or obligate (mandatory) eusociality is an important matter with regard to many social insects, and I expand on this comment when I introduce the insects below.

Despite interesting similarities in sociality between social insects and humans, attempts to apply the concept of eusociality to humans have met with limited success. Wilson (2019:69) notes cautiously that “a plausible case” can be made for (a weaker form of) eusociality in humans, citing problematic evidence associated with homosexuality and the post-reproductive lives of grandmothers. Both may be classified cautiously as members of non-reproductive castes. In Part 1.2, I expand on this matter when I discuss kinship and warfare in Aboriginal Australia.

Table 3 is of my own making. It contains a more detailed outline of the context and content of the transitions in Table 1, focusing *not* on events in the history of life in general, but rather on events in the history of *sociality*. Using Christian’s (2016:100-101) *Big History* as a starting point⁴, I prepared Table 3 in a highly detailed form for my own use, then radically simplified and relabeled it to emphasize sociality. Superficially, the chain of transitions in Table 3 resembles the Medieval Christian *Great Chain of Being* (Lovejoy 1936). It is neither encyclopedic nor exhaustive, but it focuses specifically on what I hope are representative transitions in sociality. Some of them share important traits with social insects, and some do not. Most importantly, it contains supporting data

⁴ I enhanced Christian’s (2016:100-101) timeline with material from Dyson (1985, 1988), Margulis and Sagan (1991), Marshall (2009), Maynard Smith and Szathmary (1999), Purves, Orians, Heller and Sadava (1998), Wilson (1975, 2019) and major articles in Wikipedia (2019). Also see SFI (2019).

that align Wilson's transitions with much larger issues including mass extinctions and radiations. In this context, Wilson's work makes important but localized contributions to our understanding of sociality as a major thread in Christian's *Big History*.

Historical transitions can be organized in several ways depending on the nature of the events, the level of detail, and so on. Wilson's choice in Chapter 2 certainly is not incorrect, and I use a modified and expanded version of it. Following leads from the 19th century (Sapp 2009:46) and without regard for precise mechanisms or processes that they entail, I group diverse types of transitions under three broad headings - emergence, fission and fusion – which I use informally and somewhat idiosyncratically as follows.

Emergence describes gradualistic natural selection (order from disorder), sexual selection, kin selection, group selection, perhaps the gradualistic origin of protocells and the metabolic “hardware” of life on Earth. Genetic drift might be the prime example. “Where there was one old style, now there is another, different new style.” *Fission* describes the stepwise origin of new organisms by splitting pre-existing components from old organisms. e.g., cell division, mutation, epigenetics, isolation of founder populations. Competition might be the prime example. “Where there was one, now there are two or more.” *Fusion* describes the stepwise origin of new organisms by combining pre-existing components; e.g., panspermia; dual origin theory: inserting replicative software into pre-existing protocell hardware; lateral gene transfer; symbiosis / endosymbiosis. Cooperation might be the prime example. “Where there were two or more, now there is one.” Fission / fusion cycles characterize several forms of reproduction.

I am certain there are significant errors in the Table and accompanying text. I have conducted field research dealing primarily with kinship and related topics among the Alywarra speaking Aboriginal people of Central Australia (Denham 2012), but everything else in this paper is based on published research performed by others to whom I am most grateful. The data cited here is necessarily imprecise: most dates in the timeline are approximate and dates in source articles typically contradict each other. My descriptions of transitions generally are brief but sometimes are a bit longer. Perhaps I should have expanded upon early events near the top of the Table where the foundations of evolution occurred; instead I refer you to Sapp's (2009) history of microbiology.

Column 2, Boundaries and Transitions. In Table 3, Col 2, Boundaries B1–B9 refer to transitions of a physical nature defined by heavy bombardments, asteroid impacts, climate changes, volcanic eruptions, mass extinctions and radiations. All have low probabilities of occurrence and long recurrence intervals (Hand 2014) and are marked with dark line separators. Transitions T1–T15 refer to transitions in sociality and are the main items of interest here. Comments on the transitions follow the Table. Items unmarked in Column 2 are “milestones”, probably examples of emergence, the default option that I often ignore here. In Part 1 of the paper, I skip T14 and T15, the last and first entries labeled in Column 2, and return to both in Part 2.

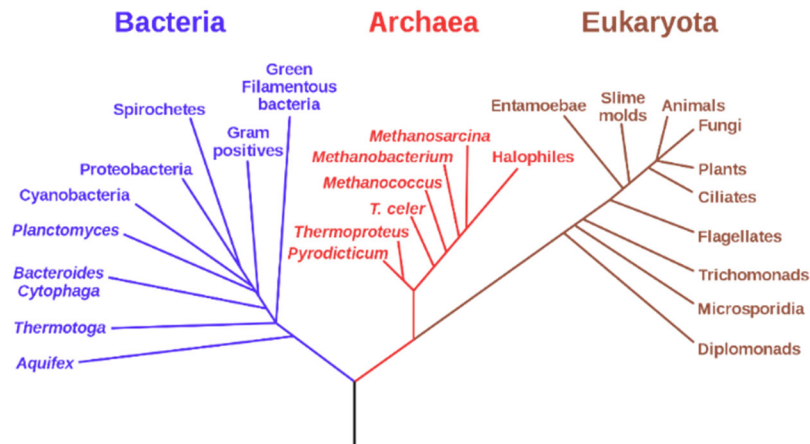
1. Date bya	2. Boundaries-Transitions	3. Event	4. Trans type	5. Data type
13.772		Estimated age of Universe		
13.51		Estimated age of Milky Way		
11.66	T15	Estimated age of M13 globular star cluster	?	
4.603		Estimated age of Sun		
4.543		Estimated age of Earth		Fos
4.00000	B1	End Late Heavy Bombardment phase		Fos
4.00000	T1	Begin life on Earth. Single origin entails emergence, double origin entails fusion of metabolic and replicative components. Either / both yield protocells.	EM / FU	DNA
4.00000	T2	Hypothetical protocells differentiate: Domain 1. Bacteria, Domain 2. Archaea. Both prokaryotes, no nucleus; asexual (mitosis) Possible appearance of Domain 3. Eukaryotes with nucleus; sexual (meiosis) All display vertical and lateral gene transfer; no tree structure.	FI / FU	DNA
3.60000		Earliest photosynthetic cyanobacteria		Fos
3.50000	T3	Earliest stromatolites or microbial mats; complex colonies of cyanobacteria	EM	Fos
2.45000	B2	Great Oxygenation boundary: mass extinction of anaerobes, evolutionary radiation of aerobes		Fos
2.20000	T4	Evidence that simple bacteria merge with bacteria; endosymbiosis yields mitochondria, chloroplasts, organelles; yields complex proto-eukaryotes	FU	Fos
1.60000	^(T4)	Evidence that proto-eukaryotes merge with archaea; endosymbiosis yields cell nucleus and highly complex Domain 3. Eukaryotes	FU	DNA
1.20000		Earliest evidence of sexual reproduction (meiosis)	FI / FU	
1.20000	T5	Earliest multicellular organisms: plants (red algae)	FI	Fos
0.75000	^(T5)	Earliest multicellular animals: sponges	FI	DNA
0.58000	T6	Earliest cnidaria yield sociality among colonial microorganisms: Hydrozoan siphonophores and anthozoan corals	FU	Fos
0.54100	B3	Cambrian radiation boundary – cryptic origin		Fos
0.53000	T7	Earliest fossils of arthropods (insects, spiders, crustaceans, etc)	FI	Fos
0.53000		Earliest fossils of fish		Fos
0.52500	T8	Earliest vertebrates yield diverse forms of sociality based on solitary reptiles, dinosaurs, crocodiles, birds, mammals	FI	Fos
0.52100		Earliest trilobites		Fos
0.50000	T9	Endosymbiosis of adaptive immune system established in earliest jawed fish chordates	FU	?
0.50000	T10	Endosymbiosis of gut microbiota established – where?	FU	?
0.44000	B4	Ordovician-Silurian mass extinction boundary; 86% of all species lost		Fos
0.41500	^(T7)	Earliest insects		Fos
0.37500	B5	Late Devonian mass extinction boundary: loss of oxygen, 75% of species lost		Fos
0.31800		Earliest reptiles on dry land		Fos
0.31200		Earliest synapsid (mammal-like reptile)		Fos
0.26000		Earliest cynodont, reptilian ancestor of mammals		Fos
0.25200	^(T7)	Earliest evidence of eusocial life among insects		Fos
0.25000	B6	Permian-Triassic mass extinction boundary: volcanic eruptions and methanogenic bacteria kill 96% of species; extinction of trilobites		Fos
0.24000	^(T6)	Earliest fossils of scleractinian corals; not reef builders, but small solitary individuals		
0.23100		Earliest dinosaurs		Fos
0.22500		Earliest mammals		Fos
0.21500	^(T6)	Scleractinian corals join with symbiotic algae and become reef builders		
0.20000	^(T7)	Earliest modern ants		Fos
0.20000	B7	Triassic-Jurassic mass extinction boundary: unknown cause; 80% of species lost		Fos
0.06600	B8	Cretaceous-Paleogene mass extinction; asteroid impact, 76% of species lost including non-avian dinosaurs; begin radiation of mammals and birds		Fos
0.05600	T11	Earliest nonverbal nonhuman primates; later yields highest sociality among hamadryas baboons, chimpanzees, bonobos	FI	Fos
0.05000	^(T7)	Earliest eusociality among some modern ants, bees, wasps, termites yields symbiotic food production, slavery, superorganisms (defined below)	EM	Fos
0.00280	T12	Earliest members of genus <i>Homo</i> yield biological radiation of genus <i>Homo</i> ; early language	FI	Fos
0.00030	T13	Begin explosive linguistic and cultural radiation of <i>Homo sapiens</i> ; origin at least as early as earliest Pleistocene cave art and probably earlier; possible achievement of Wilson's superorganism status	FI	Fos
530 bp	B9	Begin Holocene / Anthropocene mass extinction		Fos

Future	T14	Begin next transition / radiation ...?	?
Key to Table 3.			
Col. 1. Date shows timings of events in bya = "billions of years ago"			
Col. 2. Sociality transitions T1-15 and boundaries B1-9 contain counters for transitions and boundaries of interest here. Transition # in superscript and parentheses (^{T4} , T5, T6, T7) are continuations of transition # T4 , T5 , T6 and T7 .			
Col. 3. Event labels identify long durational events (e.g., aggregations of supercontinents) and shorter durational events (e.g., transitions, mass extinctions, evolutionary radiations).			
Col. 4. Transition Type = EMergence, FIssion, FUSion.			
Col. 5. Data Type = source of Col. 6 Events and Col. 7 Comments: Fos = based on fossil evidence, DNA = derived from DNA models. Table 3 is visually segmented with dark horizontal lines at major boundaries (mass extinctions, etc).			

Table 3. Major transitions in sociality among prokaryotes and animals, plus mass extinctions, radiations.

T1. The origin of protocells may have occurred by emergence (single-origin) or fusion (double-origin). Wilson implicitly accepts the single-origin RNA world theory (Gilbert 1986) of protocells in which metabolic and replicative components emerged concurrently in the same organism. Despite serious chicken-and-egg problems with that theory, Wilson skips over alternatives such as the dual-origin theory in which metabolic "hardware" and replicative "software" emerged in separate organisms and subsequently fused through symbiosis. F. Dyson (1985:1-18 and 1988:54-73) and G. Dyson (1997:28-30) strongly support a double-origin on theoretical grounds while D. Morrison (2000:270 and 2008) supports it with empirical evidence from extremophiles at volcanic vents. Also, Wilson does not mention the organic composition of carbonaceous meteorites (Pizzarello and Shock 2010), the Miller-Urey (1953) experiments that produced amino acids in a test tube, and the search for extraterrestrial intelligence (SETI). Yet he implicitly entertains the possibility of some form of panspermia when he discusses interplanetary, interstellar and potentially intergalactic searches for evidence of life.

T2. Wilson (2019:33) alludes to the idealistic T2 diagram from Woese, Kandler and Wheelis (1990). It is a minimal tree of life in three domains; viz., bacteria and archaea both of which are prokaryotes that lack cell nuclei, and eukarya that have cell nuclei. The sociality of this hypothetical array originated at some unknown early time and rests exclusively on vertical gene transfer from parent to child in the narrowly conceived Darwinian sense of evolution, i.e., descent with modification by natural selection and mutation. A generally accepted step toward enhancing the diagram's realism entails deleting the "root" and relaxing the misleading tree-like structure (Nair 2012) that results from it. Subsequent and more difficult steps entail inserting missing elements of reticulate (network) evolution including symbiosis, lateral gene transfer, hybridization and other forms of fusion that are incompatible with a Darwinian tree of life (Woese and Fox 1977; Woese 2004). I have been unable to find a diagram of reticulate evolution that presents all of these enhancements in a single package.



T2. Universal [global] phylogenetic tree based on rRNA analysis. The vertical black line at the bottom represents the root of the diagram, the last universal common ancestor (LUCA). Woese et al 1990. Diagram: [CC BY-SA 3.0: https://en.wikipedia.org/wiki/Carl_Woese#/media/File:PhylogeneticTree,_Woese_1990.PNG](https://en.wikipedia.org/wiki/Carl_Woese#/media/File:PhylogeneticTree,_Woese_1990.PNG)

T3. Stromatolites appeared by emergence. Wilson’s study of the “deep origin of societies” briefly mentions stromatolites or microbial mats (T3a), colonial bacteria of diverse species that aggregate in complex stratified structures (T3b) that are in some ways analogous to or predecessors of modern coral reefs, have been doing so without interruption for about 3.5 billion years and display some of the earliest evidence of sociality on Earth (*Wikipedia* 2019. Microbial mats). Wilson refers to the emergence of asexual reproduction by way of mitosis but omits intra- and inter-specific lateral gene transfer that is analogous to the sexual exchange of genes that appears later (Woese 2004).



T3a. Stromatolites at Sharkbay, Western Australia.
https://commons.wikimedia.org/wiki/File:Stromatolites_in_Sharkbay.jpg

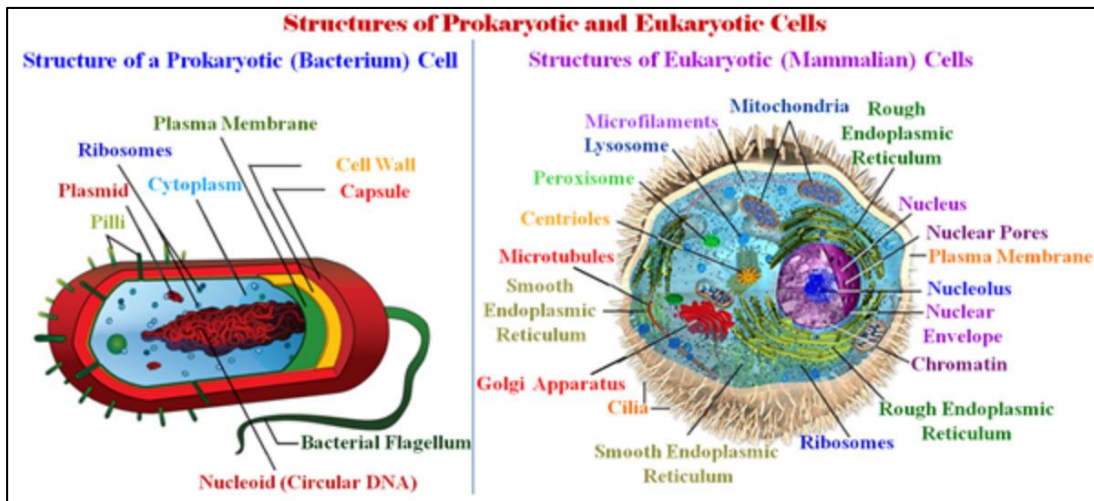


T3b. Section through stromatolite at National Museum of Nature, Tokyo.
https://commons.wikimedia.org/wiki/File:Stromatolite_-_National_Museum_of_Nature_and_Science,_Tokyo_-_DSC07686.JPG

T4. Margulis (1970, 1981) argued that the separation of eukaryotes (with nuclei) from prokaryotes (without nuclei) occurred as a result of endosymbiotic fusion whereby bacteria presumably

ingested other bacteria resulting in the formation of mitochondria, chloroplasts and other internal organelles, and presumably ingested archaea that formed the cell nucleus in a multi-step process spanning about 600 million years. In this scenario, eukaryotes thereby resulted from the repeated fusion / symbiosis of several forms of life. This complex transition was accompanied by the simultaneous emergence of DNA from RNA, and the emergence of sexual reproduction in the form of meiosis. The schematic diagrams in T4a-b reasonably well depict the relative simplicity of the true bacteria and the complexity of the eukaryotes, but do not depict archaea at all, most of which are extremophiles that have exceptional and diverse appearances and live in such challenging habitats as volcanic vents. The “evolutionary distance” between transitions T2 and T4 is enormous and possible links between those phases remain elusive⁵.

My brief summaries of transitions T2 and T4 are incomplete pointers toward a massive literature on molecular evolution and endosymbiosis summarized by Sapp (1994, 2009) and others.



T4a. Prokaryotic cell

T4b. Eukaryotic cell

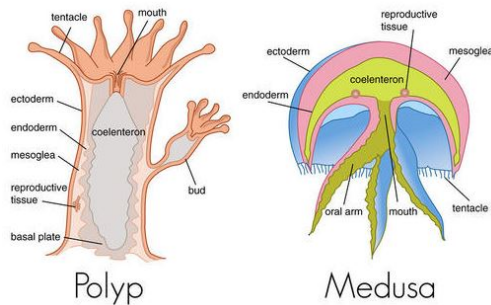
<https://nptel.ac.in/courses/104103018/module1/lec6/1.html>

T5. Fusion yielded multi-cell eukaryotes and fission separated them into multiple phyla in another 2-step process spanning about 450 million years. The emergence of 2-layer and 3-layer organisms facilitated the emergence, specialization and integration of organs, tissues and networks within organisms. Those diverse organisms showed minimal to extreme sociality among their own organs and other body parts.

T6. Wilson (1975:379-393) provides a fine introduction to phylum cnidaria’s siphonophores and corals, but he omits them from *Genesis*. I amplify on his earlier work.

⁵ Sapp (2009:98) notes that the prokaryote-eukaryote distinction was established firmly by Stanier, Doudoroff and Adelberg (1963) and generally accepted by their peers only after three centuries of intensive debate terminated by the invention of the electron microscope by Ernst Ruska in 1931 (Nobel Prize in Physics 1986).

T6a. Members of phylum cnidaria are the simplest animals in which cells are organized into tissues. The phylum hosts about 11,700 species of multicellular marine microorganisms, a great many of which are colonial. I discuss only two of them, hydrozoan siphonophores with 188 known species and anthozoan corals with about 6100 known species (WoRMS 2018). Earliest known fossils appeared at 0.580 bya. Within this phylum, simple organisms working together give rise to remarkably complex siphonophores and to remarkably persistent coral reef builders that have constructed Earth's largest structures of biological origin. Transitions by both fission and fusion are active here.



T6a. Cnidarian structural phases.

CK-12 Foundation:

<https://www.ck12.org/biology/Cnidarian-Structure-and-Function/lesson/Cnidarian-Structure-and-Function-Advanced-BIO-ADV/>

Generally speaking, cnidaria have complex life cycles featuring two phases (T6a), a sessile polyp phase that attaches to a substrate and forms an expanding colony that replicates by means of asexual budding, and a motile medusa phase that uses sexual reproduction to establish new, independent colonies (Wikipedia 2019. Cnidaria). Unfortunately for us, neither siphonophores nor corals follow this simple generic pattern. Siphonophores are fully motile and omit the sessile phase while corals are fully sessile and omit the motile phase. Nevertheless, both produce truly remarkable colonies based on variations in the same reproductive strategy but are held together by fundamentally different forms of bonding.

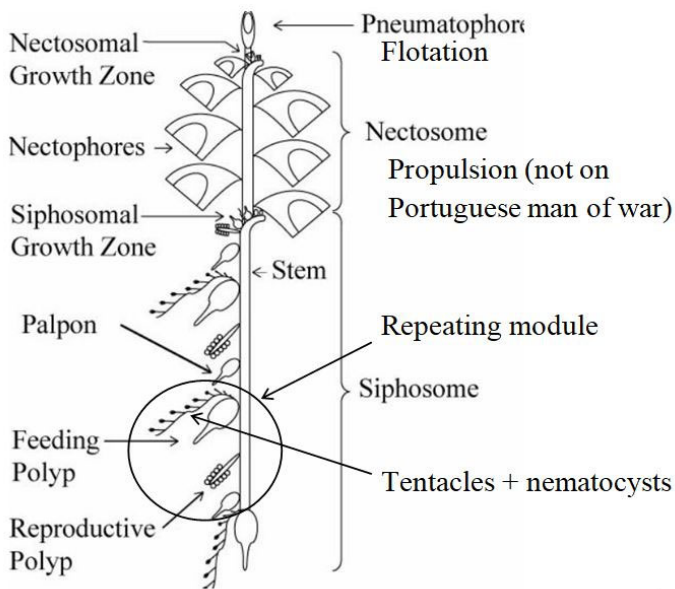
T6b-c. Most siphonophores are deep ocean dwellers (Dunn 2005a-b) and may be up to 50 meters long with a fragile connective stem that is two cells in diameter (T6b). But two members of the class live on the ocean surface and appear to be radically different from other members of the phylum. These surface dwellers, with large flotation cells atop their colonies, are the Atlantic or Portuguese man o' war *Physalia physalis* (T6c) with a 30 cm float, and the smaller but otherwise similar Pacific or Australian blue bottle *Physalia utriculus* (species status challenged) with a 10 cm float.

Both sexual and asexual reproduction occurs in these animals. Sexual reproduction produces new free-floating colonies that ordinarily are solitary but may congregate in the autumn in clusters of a thousand or more. Each colony, either male or female, forms gametes that it sheds into the water where a sperm of one colony joins an egg of another. When such mass fertilization occurs, many young colonies are seen during the following winter and spring (Kurlansky, M. 2002).

In T6b, asexual reproduction occurs at any time and produces new members of existing colonies by mitotic division or budding (Hoover 2008) at the growth zones. Polyps generated at the growth zones become specialized for flotation, feeding and digestion, and reproduction, with offensive-

defensive tentacles (Ansarov/NGS video 2014) equipped with organelles called nematocysts. Nectophores, which are medusas rather than polyps, provide propulsion in deep ocean siphonophores but are absent from surface dwellers who sail with the winds and currents. Members of these distinct castes are occupational specialists but are permanently bound to the colony. All of the pieces when put together resemble a medusa-like jellyfish, but in fact they constitute a single colony of polyps with perhaps thousands of analytically separable but structurally integrated microorganisms sharing common life support systems that circulate nutrients and sensory information.

Surface dwellers clearly diverged from their benthic relatives when they gained flotation cells and lost their means of propulsion, but in most other regards they retain membership in the hydrozoan class. Apparently, the highest degree of complexity is achieved by *Physalia physalis* which, after perhaps 500 million years (frequently repeated but unsubstantiated) of evolution, have been called variously the most complex and the most puzzling of all living creatures. This brief summary is weak due to difficulties in locating the animals, their fragility, and their intrinsic complexities.



T6b. *Physonect* colony

<http://www.siphonophores.org/SiphPlan.php>

Also see Maynard Smith and Szathmary 1999:134.



T6c. *Physalia physalis* Portuguese man of war

<https://www.pri.org/file/photo-6129-credit-casey-dunn-brown-universityresizedjpg>

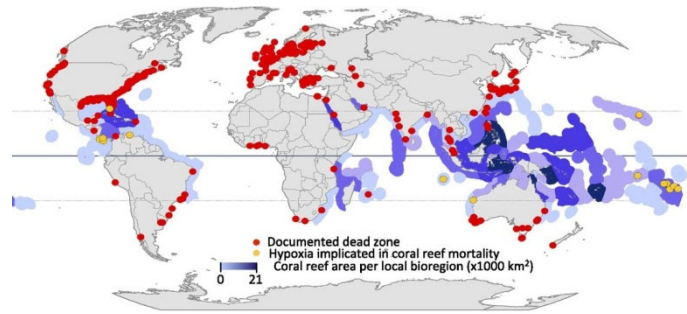
T6d-e. Coral animals are different from – yet similar to - siphonophores as indicated above. Yet modern coral reefs and coral reef biomes are strikingly different from ancient reefs which were not built by corals. As early as 0.540 bya, Paleozoic reefs were built by a wide array of cyanobacteria, algae, sponges and mollusks, with minimal contributions by now-extinct solitary coral polyps. After experiencing multiple extinction events before 0.200 bya, those ancient reefs

finally became extinct and modern reefs built mainly by colonial scleractinian or hard corals became abundant and massive (Veron et al. 2019).

Members of order scleractinia build colonies of stony coral polyps held together by calcium carbonate that the animals secrete to form hard exoskeletons. Most shallow water corals such as those in Australia's 20,000 year old Great Barrier Reef obtain the majority of their energy and nutrients from endosymbiotic photosynthetic unicellular algae that have resided within their tissues (NOAA 2014) since about 0.215 bya, and are threatened now with bleaching and extinction by rising global temperatures. Unlike siphonophores for whom data is limited, copious data is available for corals due in part to concerns by many about their possible extinction during the 21st century.



T6d. Coral outcrop at Flynn Reef near Cairns, Queensland. 23 July 2010. T. Hudson - Own work, CC BY-SA 3.0.
https://en.wikipedia.org/wiki/Great_Barrier_Reef#/media/File:Coral_Outcrop_Flynn_Reef.jpg



T6e. Distribution of coral reefs on Earth. Each of the six Asian Coral Triangle countries has at least 500 species of reef-building corals. Altieri et al 2017 <https://doi.org/10.1073/pnas.1621517114>

Symbiosis characterizes relations among coral animals, the reefs they create and the reef biomes in which they exist. T6d is a complex coral outcrop on the Great Barrier Reef not far from the Asian Coral Triangle (*Wikipedia*, 2019. Coral Triangle 8-14-19) region of Southeast Asia. T6e is a sketch map that includes parts of the Coral Triangle in Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste. The western boundary of the Triangle is Wallace's Line; its eastern extension is the Great Barrier Reef. Each ecoregion within the Triangle has at least 500 species of reef-building corals, and the region as a whole has more than 2,200 species of reef fish, all of which survive to some extent cooperatively, many in symbiotic relationships, in what the World Wildlife Fund (2019) calls the "global center of marine biodiversity".

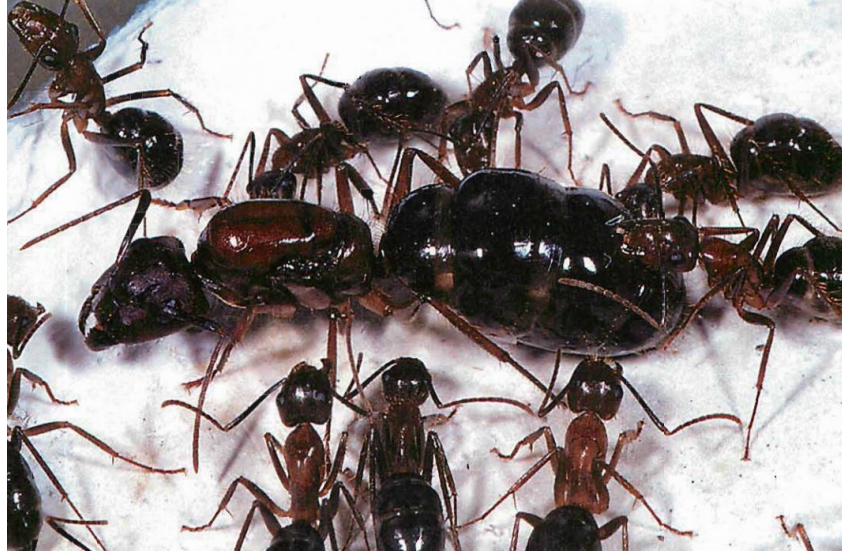
The two species of cnidarians briefly introduced here are not among human ancestors, but they are representative of thousands of diverse colonial species within their phylum and constitute important case studies in the evolution of sociality (Dunn 2005a, 2005b, Dunn and Wagner 2006; Mapstone 2014; Steele et al. 2011; Shale et al. 1987; Wilson 1975).

T7. Wilson specializes in the social insects - ants, bees, wasps and termites – that independently developed lesser or greater degrees of sociality featuring altruism, caste systems and eusociality with deepest roots at about 0.415 bya, becoming clearly visible in the fossil record at 0.252 bya,

and achieving its present day form as recently as 0.050 bya. A small sample of Wilson's work is listed in the References below and an eminently readable and accessible summary of his research with ants appears in Wilson (2010) *Anthill: A Novel*. Part IV. The Anthill Chronicles.



T7a. *Oecophylla smaragdina*
Weaver ants. *Superorganism*.
Holldobler and Wilson
(2009:Fronticepiece Plate 1).



T7b. *Camponotus floridanus*, queen and workers.
Superorganism. Holldobler and Wilson (2009:285 Plate 37).

<https://s3.amazonaws.com/arena-attachments/600990/b755d438a9c620ddcfea4d82799b77e0.pdf>

The highest degree of sociality among these insects is achieved by societies featuring complex fission of two or more physically distinct castes far exceeding sexual dimorphism, with divisions of labor and reproductive altruism, and symbiotic fusion of some ant species with other ant species and with fungi that yield close approximations to slavery and agriculture. Elaborate communication systems feature pheromonal, auditory, tactile and visual channels facilitating unidirectional and reciprocal messaging between individuals, and group-oriented messaging between individuals and the colony, caste and brood concerning dominance relations within which genealogical and kinship data are embedded, plus various categories of work-related transmissions.⁶ And honeybees perform their famous waggle dances. As was true of the colonial microorganisms described above, these societies are not in the direct line of human descent, but as Wilson and his many colleagues (1971, 1975, 2019; Hölldobler and Wilson 2009) have demonstrated, they provide valuable insights, analogies and parallels for research on human societies. Sometimes it is easy to forget that the findings are analogies.

⁶ Attenborough (2017) shows these communication systems in action among red wood ants *Formica lugubris* in the Jura Mountains of Switzerland.

T8. Vertebrate fission yielded diverse forms and degrees of sociality based on mix-and-match independent or solitary animals. Among fish and their descendants (reptiles, dinosaurs, crocodiles, birds and mammals), some remained solitary except for mating; some were members of herds, schools, flocks; some were members of more formally organized communities. Their highest degree of social complexity (excluding humans) was achieved relatively recently by nonhuman primates.

T9. Modern humans have two immune systems - innate and adaptive - the former an early, fast acting, limited form, the latter a slower acting but more robust form with a built-in memory of prior attacks by pathogens. The ability of the innate system to distinguish between self and not-self, which is crucial for our survival, is present in bacteria and conspicuous in cnidaria (T7) where genetically identical coral fragments can fuse in a mechanical sense with members of their own colony, but probably will not fuse with more distant kin from genetically distinct colonies (Forsman et al. 2015). The adaptive system, on the other hand, has its roots in fusion, endosymbiosis and coevolution that began about 500 million years ago in the earliest jawed fish. Essentially the same complex adaptive immune system is found in all animals that descend from those earliest chordates. Apparently, these systems – among the very oldest kinship systems - worked well from the very beginning and have not changed much (Flajnik and Kasahara 2010).

T10. The modern human digestive system contains a gastrointestinal microbiota of more than 400 species – some say as many as 1000 species - of bacteria, archaea, eukarya, fungi, viruses and other symbiotic microbes that have co-evolved with human hosts, with each other and with the human adaptive immune system. For example, Arumugam et al. (2011) have identified robust clusters of co-residing species that constitute well-balanced host-microbial symbiotic states or enterotypes suggestive of blood types. “While individual host properties such as body mass index, age, or gender cannot explain the observed enterotypes, data-driven marker genes or functional modules [correlate with] each of these properties; [e.g.] twelve genes significantly correlate with age and three functional modules [correlate] with the body mass index” (Arumugam et al. 2011:174). These endosymbiotic patterns leave little evidence behind, so I have found no information about ancient origins (Davenport et al. 2017; Thursby and Juge 2017).

T11. “Nonverbal nonhuman primates”, as I use that expression here, include prosimians, monkeys, apes and extinct hominids excluding members of genus *Homo* (I deal with all of genus *Homo* under Transition 12 below). Fission among the species included here yielded diverse forms of sociality involving solitary individuals; monogamous and polygynous nuclear families, complex band communities, etc. R.E. Morrison et al. (2019) present detailed quantitative field research concerning narrowly defined evolutionary transitions in the sizes and compositions of foraging kin-based groups among gorillas (before their evolutionary separation from chimpanzees), while Foley and Gamble (2009) shift their focus to similar transitions among early hominids (shortly after their separation from chimpanzees). Their micro-level papers closely parallel the macro-level coverage of this article.

T12. The origin of language remains unknown and is a topic that I approach with trepidation. I speculate that among genus *Homo*, mutations or major epigenetic events yielded varying degrees of language capacity. Emergence of new forms of sociality among near-humans may have been based on acquisition of a language capacity, perhaps inferior in quality and complexity to that of *Homo sapiens* but with similar skills in linguistics, speech production, hearing, language analysis and so on. Wilson (2019) deals exclusively with *Homo sapiens* (cranial capacity 1,200-1,450 cm³) but I omit our species at this point, instead dealing with species that he explicitly avoids mentioning. Other potentially verbal *Homo* species include *Homo erectus* (cranial capacity 850-1100 cm³), *Homo denisova* (unknown cm³), *Homo neanderthalensis* (1300-1600 cm³) and other archaic humans with brain sizes averaging 1,200-1,400 cm³, thus overlapping or exceeding the cranial capacities of modern humans. Wilson also ignores “many examples of interbreeding between ancient human groups” (Warren 2018). Sociality based on language capacity among one or several species accepts the possibly concurrent presence of language capacity in other *Homo* species in addition to our own. Our lack of knowledge does not imply their lack of speech.⁷

T13a-o. Among *Homo sapiens*, it is possible, even probable, that early fission yielded multiple versions of sociality based on linguistic, cognitive and cultural traditions, but data is lacking. Speculating about the deep history of transitions in human kinship, Read (2019:1) says:

“... our ancestors worked out [a transition] from the individualistic, face-to-face systems of social interaction of the great apes to the relation-based systems of social interaction that characterize human societies. This transformation [occurred] through the ... intellectual achievement of working out computational systems of kinship relations expressed through kinship terminologies.”

However, as I noted above at T11, R.E. Morrison et al. (2019) has shown that the gorillas he studied had more than a passing behavioral acquaintance with some of the finer points of primary kinship relations but had no language with which to express them. Likewise, Wilson (1975), Hamilton (1964) and many others have shown that ants have practiced kin selection for about 50 million years with no vocabulary to discuss it.

Approaching history from the “opposite direction”, Allen (2007) has shown a plausible way to construct a kinship structure and vocabulary that looks remarkably like some found in Australian Aboriginal societies. He says that “The quasi-mathematical aspect of kinship, which has much less to do with statistics than with the logic of relations, renders it possible to answer the question: “What is the simplest logically possible kinship system?” (Allen 2007:45). Then he builds it for us, first reminding us of the biological and psychological bases of dispersion and inbreeding avoidance among humans, nonhuman primates and many other species of animals (Wolf and Durham 2004 passim).

⁷ See Leaf and Read (2012) for recent discussions of issues addressed in T12 and T13.

Here I paraphrase and compress Allen's argument. His hypothetical society is tetradic like Aboriginal section systems, with separate groups of male and female biological and classificatory siblings occupying each of four quadrants - A, B, C, D - that can be coded in pheromones, body paints, words, etc. Descent is recognized in male lines and is present but perhaps not acknowledged in female descent lines. To keep it simple same-sex mating is prohibited. Men avoid inbreeding by *not* mating with women in their own quadrant or in either of their parents' quadrants, which means they must mate with women from the only other quadrant; i.e., the one in their own generation but in the opposite descent line. For example, when an A male mates with a B female, their son is a C male and can mate with a D female in a pattern that repeats through the generations. So long as people remember and respect the quadrants to which they and their permitted mates belong, they avoid inbreeding too closely or outbreeding too distantly and the rudimentary kinship system does one of its jobs well without detailed and potentially complex verbalized kinship terms. But relative positions of individuals in the quadrants are preadapted for the addition of more detailed labels should A, B, C and D be insufficient. The resulting construction looks a lot like a major historical transition in the making. Still, it is not obvious how our ancestors reached across the gap from gorillas to geometry.

Representative human cultural formations incorporating kinship terminologies and other intellectual achievements are suggested here by common names for "traditional ways of seeing" arranged in something vaguely resembling a chronological order:

- T13a-b. Hunter-gatherers: Europe and SE Asia (a. Pleistocene cave art: Aubert et al 2014) and Aboriginal Australia (b. Dreamtime tradition)
- T13c-n). Food producers: East Asia (c. Confucianism, d. Taoism, e. Shintoism), South Asia (f. Hinduism and g. Buddhism), West Asia (h. Judaism, j. Christianity, k. Islam), Central and South America (l. Aztec, m. Maya, n. Inca traditions)
- T13o. Scientific, industrial, technical traditions originating mainly but not exclusively in Europe (o. science)

Summary.

Table 3 is highly selective and incomplete, but it provides a modest sample of several kinds of major transitions beginning 4.5 bya, a unique and "long sequence of stochastic ... events that led to our evolution" (Sagan 2006:121). A rough count of T1-T13 shows 9 boundaries and 14 transitions including 3 emergences (and others unmarked by default), 7 fissions and 6 fusions, some of which are complex or ambiguous. Emergences and fissions are compatible with a divergent or competitive model; however, the fusion of metabolic and replicative components in the double-origin theory (if applicable), the lateral gene transfers and endosymbiosis that yielded eukaryotes, and the establishment of the adaptive immune system and the gut microbiota as endosymbionts seem to fit more comfortably into a convergent or cooperative model. In the presence of so much fusion and other forms of cooperation, it remains risky to build a universal theory of evolution (biological, cultural, planetary, cosmic, and so on) that rests too heavily on competition.

The chronologically ordered sequence of events in Table 3 may or may not be accurate, but in either event the intertwining of several descent lines makes it difficult to read. I attempt to deal with that matter here. I suggest that the decision by various writers to assign an arbitrary number of transitions – typically six - to the whole history of evolution on Earth is an excessively sharp application of Occam’s Razor. It is easier and probably more informative to construct evolutionary descent lines with variable numbers of transitions in them. For example, bacteria and archaea have only two transitions (T1, T2), stromatolites have three (T1, T2, T3), and eukaryotes have three (T1, T2, T4). The fission that yielded Plantae and Animalia has four (T1, T2, T4, T5). Excepting stromatolites, the pattern to this point is a simple cumulative sequence.

From about 0.580 bya, I focus exclusively on diversity within T5 Kingdom Animalia, skipping levels and descent lines in the hierarchy that are unused. Thus, for my purposes, I split T5 at the phylum level into T6 cnidaria, T7 arthropods and T8 vertebrates.

- T6 cnidaria holds two parallel descent lines. Hydra with special reference to siphonophores (T6b-c) are in one line; anthozoa with special reference to corals (T6d-e) and specifically scleractinian corals are in the other.
- T7 arthropods holds the insects with special reference to diverse social insects, but it could include crustaceans also.
- T8 vertebrates holds fish, amphibians, reptiles, birds and mammals with special reference to the primates (T9, T10, T11, T12, T13). The details that appear in the primate line may have comparable parallels in other descent lines as well.

Despite his book’s subtitle – *The Deep Origin of Societies* – Wilson focuses on events in the evolutionary history of humans, plus only one other group of animals - social insects - that began about 0.250 bya. By any reasonable standard, the sample is quite small, and the onset date of the social insects is not especially deep: less than a tenth of the time since life began on Earth. If we really want to consider deep origins, it is reasonable to start nearer the beginning and compare human sociality transitions with a more diverse sample of transitions for which admittedly imperfect data exists. I have attempted to do that in Part 1.1 of this paper.

1.2. Obligate eusociality in hunter-gatherer societies.

Wilson (2019:107-125) in Chapter 6 tells “The Human Story” which ends with a discussion of warfare and kinship in hunter-gatherer societies. I have some problems with it. Here I return to the recurring themes of kinship, altruism, selection and eusociality.

Part of Wilson’s (2019:116) argument with regard to humans, as I understand it, is that warfare (aggression) is a nearly universal feature of chimpanzee and human societies. It may happen sometimes within bands of 5-10 members (close kin within nuclear or minimally extended families); it is most common between bands of perhaps 25 people including several kin within a larger community of less than 150 people; and sometimes it occurs between those larger communities with less dense kin relations. It appears that intra-band and intra-community conflicts, generally among close kin, hinge on specific interpersonal relations associated with

mating and marriage, or disagreements over other local matters, while inter-community conflicts between, on average, less closely related individuals generally hinge on control of territory and resources. Wilson sums up the situation by quoting his colleague David Sloan Wilson (D.S. Wilson and E. O. Wilson 2007:328): “He says that within groups, selfish individuals will defeat altruistic ones. However, in conflict, groups of altruistic individuals will defeat groups of selfish individuals” (Dreyfus 2019). In the context of multilevel selection, individual selection favors people who are the best competitors, while group selection favors individuals who altruistically and cooperatively work best together, traditionally as members of kin groups such as bands or communities.⁸

Wilson says: “Group selection is a big part of the great transitions of evolution, where life progressed from bacteriumlike organisms to cells with structures inside, and on to simple organisms that were collections of these cells, to the differentiated organisms forming groups and so on. [In *Genesis*], I presented these transitions against the backdrop of group versus individual selection” (Dreyfus 2019).

When I introduced the six-point sociality scale near the beginning of this article, I indicated that Wilson’s definition of eusociality required the presence of all six traits in co-residential social groups bound in part by genetically and demographically structured kinship whose degree of relatedness between pairs can be calculated by Hamilton’s (1964) Rule. You can study that rule from a multitude of sources and perspectives on the web. Some social insects and a small number of non-insect species are eusocial but to a lesser degree than the maximal version. Most importantly, maximal or obligate eusociality theoretically precludes intra-societal warfare over reproductive rights within and between castes but may encourage inter-societal warfare (Hölldobler and Wilson 2009:44) over territory and resources. Only some species of social insects achieve the highest level of obligate eusociality that ranks them as “superorganisms”, generally with millions of members in each colony, complex caste systems featuring altruistic behavior, symbiotic relations with other species, subtle and elaborate multimodal communication systems, elaborate architecture, etc. Among social insects, “superorganism” has a precise technical definition resembling the one sketched here, but among humans the term is used analogically, especially with regard to caste which has a biological definition among insects and a social definition among humans.

In this context, relationships between kinship and warfare are problems and speculation concerning hunter-gatherer warfare goes deep. In 17th century European philosophy related to hunter-gatherer societies, the “war of all against all” encompassed all forms of deadly human violence (war, feud,

⁸ There is great room for confusion among 1) Darwin’s (1872) individual level selection, 2) Dawkin’s (1976) gene level selection, 3) Hamilton’s (1964) individual level kin selection and 4) Wilson and Wilson’s (2007) group selection which actually is a form of individual selection operating as the upper level in a two-level selection process. Wynne-Edwards’s (1962) and Lorentz’s (1966) species level group selection was rejected by Wilson (1975), Dawkins (1976) and many others and fell out of favor because it contravened orthodox Darwinian theory’s demand for individual level selection. In part, the paper by Wilson and Wilson (2007) represents half a century of research aimed at overcoming weaknesses in Wynne-Edwards’s (1962) argument.

homicide, spouse and child abuse; inter-societal and intra-societal conflict), while the “noble savage” was ostensibly free from all forms of human violence (Hobbes and Rousseau paraphrased by Gat 2015:114). Those two extreme views have alternated in- and out-of-fashion for centuries, with mid-20th century anthropology represented by Elkin (1938/1954) and Berndt and Berndt (1964) preferring the “noble savage”, and early-21st century anthropology represented by Gat (2008 and 2015) and Bowles (2009) preferring “all against all” bordering on “nature red in tooth and claw”. The pendulum no doubt will continue to swing.

Presumably statistical data would be useful here, but due to profound problems with data quality it actually isn't. The closer we get to the data, the more confusing it becomes.

Elkin's (1938/1954) classic introduction to Aboriginal Australia makes no reference to warfare; he acts as if it doesn't exist, and that may be precisely what he means. Likewise, in a 600-page survey of Australian Aboriginal societies, Berndt and Berndt (1964:356-59) devoted only 3.5 pages to a comprehensive review of “Feud and Warfare”. Both books, based largely on field experience, acknowledge the importance of cooperation and clearly argue that warfare was virtually nonexistent throughout the continent except in northern Arnhem Land in Australia's Northern Territory. The Berndts (1964: 358) say “the most highly organized warfare in Aboriginal Australia was found” there but knowing precisely what they mean is not easy.

On the other hand, Gat and Bowles reach back into 19th and early 20th century field reports from Australia and elsewhere to find relevant discussions and, hopefully, ethnographic data. As a result, Bowles (2009:1294) presents archeological and ethnographic data concerning mortality rates attributable to warfare in 23 hunter-gatherer societies worldwide.

Three were in Aboriginal Australia⁹ and all were near neighbors of each other in north and northeastern Arnhem Land. Thus, out of a total of approximately 600 traditional Australian Aboriginal societies, Bowles picked a tiny cluster of 3 neighboring, anomalous Arnhem Land societies with poor but cautiously quantifiable data. On the surface they seemed to be better than nothing at all, but they were by no means representative of the remaining approximately 597 Australian Aboriginal societies.

This cluster of Arnhem Land societies is unsuited for Wilson's task for reasons related to ecology, history and eusociality that collectively yield a paucity of reliable data.

Ecologically, Read and LeBlanc's (2003) model of hunter-gatherer demographics implies that the likelihood of warfare in such societies varies directly with resource density. This contrast characterizes most if not all of Australia and clearly differentiates between the rich resource area in Arnhem Land and the poor resource areas throughout the interior of the continent. Since this

⁹ The societies reported by him had diverse names: Murngin (or Yolngu near Yirrkala; Warner 1930, 1937), Tiwi (on Melville and Bathurst Islands: Pilling 1968) and Anbara (or Burara or Gidjingali near Maningrida: Hiatt 1965).

consideration applies worldwide, it raises questions about the habitats of other societies included in Wilson's sample of 23 cases.

Historically, we know that data recording, even by well-meaning observers in the late-19th century and the first half of the 20th, occurred during a grim period of the "stolen generations" of Aboriginal children, complicity by anthropologists and government officers in widespread biological and cultural genocide, forced assimilation of Aboriginal people on government settlements and at the hands of Christian missionaries, and so on almost indefinitely (Gray 2007).

Furthermore, statistical analysis of those data, then and now, occurred under the black cloud of endless competition cast by Adam Smith, Thomas Malthus, Charles Darwin, European colonialism, social Darwinism, eugenics, the Holocaust, and racism continuing into the 21st century. Trusting data on warfare collected, processed, analyzed and reported by "the winners" under such conditions requires an enormous – and I think unjustified - leap of faith. Rather than forcing data to match theory, perhaps we should admit that we don't know what the data might have said, and deal with what we do know.

The problem with eusociality is more subtle. Wilson unfortunately accepted Bowles's problematic data about hunter-gatherers to bolster his larger arguments concerning relationships between individual and group selection, and warfare. Certainly, I cannot speak for hunter-gatherers worldwide or Aboriginal Australians continent-wide, nor can I argue strongly from a sample of one. But I can speak for the Alyawarra-speaking people of Central Australia who I consider to be far more representative of the continent as a whole than the three societies recommended by Gat, selected by Bowles, and cited by Wilson.

Elsewhere (Denham 2015) I have reported that the Alyawarra eschewed violence and had intricate, highly redundant networks of relationships that prevented it. Those networks were based on genetic relations reinforced by known deep ancestry, sex, age, generations, marriages, descent and generation moieties, two interdigitated kinds of kinship terminologies, section and subsection systems, comprehensive alloparenting of all children, and other features. The networks tied people to each other, to the land and its resources, to members of at least ten neighboring societies with whom they intermarried, and to the ancient cognitive world of the Dreamtime and their ancestors in it. Collectively this massive and intense relational network of networks, far more complex than any caste system, did not preclude transient conflicts between individuals, but would have made warfare in any sense totally counterproductive under any circumstances. The mantra that dominated the society simply said, "We take care of them".¹⁰

¹⁰ Thanks to Paul Ballonoff for comments on Wilson's work with the biological bases of kinship, kin selection and related topics that have generally gone unrecognized by anthropologists who specialize in studies of human kinship.



T13a-b. Australian Aboriginal Dreamtime 1971. Above. Alugera, residence for unmarried women and children. Includes windbreak, shelter, shades, areas for cooking and sleeping. Below. Men pluck eagle down in preparation for a circumcision, a major transition in the lives of Aboriginal men. Photographs by author.

But a more serious problem here is that Gat, Bowles and Wilson use data that ostensibly demonstrates not only the prevalence but also the benefits of warfare (whether intra-societal or inter-societal is not specified) even though Darwin (1872), Gould (1997), Wilson himself (2019) and many others have noted that “those who acquire habits of mutual aid are undoubtedly the fittest” (Kropotkin 1902).

In other words, if Wilson were to accept the weakness of Gat’s and Bowles’s positions on Aboriginal warfare (except in northern Arnhem Land) without trying to make something out of

nothing, he (and I) could argue convincingly that the Alyawarra satisfied the mandatory criteria for eusociality AND showed no evidence of either intra-societal or inter-societal warfare. That does not mean that misunderstandings and arguments never occurred, but with regard to warfare as that term is used in the ordinary English language¹¹, they exceeded Wilson's requirements for classification as a superorganism.

Then, by Wilson's standards, the Alyawarra – and perhaps many other Australian Aboriginal societies for whom persuasive evidence of warfare does not exist - would stand at the very peak of human sociality, far from being one of the most primitive and least civilized of societies as ethnocentric Europeans have labeled them since 1788. Their technology was very simple, but the superorganism peak on the eusociality scale says nothing about technology anyway.

Part 2. Imagining the future.

Turning away from the near and distant past, I use Wilson's *Genesis* as a steppingstone toward two possibilities in the near and distant future.

2.1. Predictive applications of sociality research.

In the second paragraph of "The Human Story", Wilson (2019:107) says:

"Only one of the multitude [of nonhuman species] has reached the human level of intelligence and social organization. With that singular event, everything on the planet changed. Thereafter there would be no other candidate and no further contest."

I understand that to mean that in Wilson's opinion evolution has ended. Perhaps he expects us to destroy ourselves pretty soon, in which case he may be right. Or he may believe that the human species in the 21st century has achieved the highest possible form and level of sociality. Whatever it means, Table 3 suggests that the history of life on Earth can be seen less pessimistically as a work in progress, albeit filled with numerous major bottlenecks. I agree that "Man is a transitional animal ... not the climax of creation" (Sagan 1973a:5).

Wilson, who criticized Hamilton for failing to make predictions, gave us no help with regard to analyzing future transitions based on *Genesis*. Unless we do something extraordinarily stupid that eliminates life on Earth or tosses us back into the Stone Age, Transitions T1 through T13 can be seen optimistically as trajectories leading toward one or several of the overlapping options suggested below in Transition T14. Chapter 8, the final chapter in Christian's (2016:304-359) *Big History*, begins in about 1750 with the onset of the Industrial Revolution. It surveys European colonial empires, medical developments, renewable and nonrenewable energy, transportation, communications, the population explosion, climate change and so on, then concludes in 2016 with

¹¹ See Biletzki and Matar (2018) concerning Wittgenstein's (1953) "turn from formal logic to ordinary language", which may resemble Wilson's "turn from Hamilton's Rule".

the question “Where next?”. Christian’s brief comments on possible lines of development are valuable teasers but they make no attempt to deal with the future *in toto*. Among the nearly infinite number of possible trajectories, I attempt to sketch a few that may be more likely than others.

Hypothetical peaks of future sociality derived from the world as it is today suggest that diversity means variations on a common theme of space travel: interplanetary, interstellar and, in the really remote future, intergalactic. I do not write science fiction, but I include examples of it here as a bridge between the sciences and the humanities (Snow 1969, Wilson 1998, Gould 2011).

For people who are skeptical of science-fiction, the footnote¹² highlights the backgrounds of authors cited in T14a-h.

T14a. Bernal (1929). We may extrapolate directly from early 20th century space exploration and human biology. Arthur Clarke (2000) called Bernal’s small book “the most brilliant attempt at scientific prediction ever made” (cited by Andrew Brown, 2005:70). Bernal’s proposals entail speciation by means of both fission and fusion.

T14b. Dick and Lupisella (2009-NASA). We may enter a post-biological world based largely on extrapolations from current computational technologies, robotics and genetic engineering. The articles in the NASA volume lead to both fission and fusion.

T14c. Sagan (1973b). We may learn that extraterrestrial life is real (panspermia, SETI). Then suddenly we as members of a species who fancies itself unique must cope with the fact that it has fallen off its metaphorical pedestal regardless of which details prevail. Implications for sociality are not clear.

¹² Minimal credentials of authors cited in T14a-h. **ASIMOV.** PhD in biochemistry; author of future histories: *Foundation* series, *Robot* series, Three Laws of Robotics, artificial intelligence, psychohistory; multiple Hugo and Nebula awards. **BANKS.** Science fiction and literary novelist; creator of *Culture* series. **BERNAL.** Pioneered X-ray crystallography in molecular biology; Professor of Physics at Birkbeck College, University of London; Fellow of the Royal Society. **CLARKE.** Author *Rendezvous with Rama*, (with Stanley Kubrick) *2001: A Space Odyssey*; geostationary satellite orbits; knighted in 1998. **DICK.** PhD in History and Philosophy of Science; NASA Chief Historian; established NASA Astrobiology Institute; NASA/Library of Congress Chair in Astrobiology. **DYSON.** Theoretical physics and mathematics; author: *Disturbing the Universe*; lifetime tenured professor at Institute for Advanced Study, Princeton University; 1988 Gifford Lecturer; WWII British Bomber Command. **HOYLE.** Mathematics at Cambridge; stellar nucleosynthesis; author: *The Black Cloud*; knighted in 1972; President, Royal Astronomical Society. **KARDASHEV.** PhD in Physical and Mathematical Sciences; astrophysics, astrobiology; Moscow State University; USSR and Russian Academy of Sciences. **LE GUIN.** Daughter of anthropologist A. L. Kroeber, Fulbright scholar, author: *The Dispossessed*, Pulitzer Prize nominee, member of American Academy of Arts and Letters. **LUPISELLA.** PhD in Evolutionary Biology; NASA scientist and engineer; robotics; Hubble Space Telescope; microbial contamination of Mars. **SAGAN.** PhD in Astronomy and Astrophysics; author: *Cosmos* TV series, *Voyager Golden Record*, *Murmurs of Earth*, Pulitzer Prize in General Nonfiction; 1985 Gifford Lecturer. **STAPLEDON.** PhD in Philosophy; author of nonfiction, future histories *Star Maker*; Dyson spheres, genetic engineering, terraforming.

T14d. Asimov (1942-1993). We may embark upon 20,000 years of sociality based on artificial intelligence, positronic brains, robotics and Hari Seldon's mathematical psychohistory which epitomizes long term prediction, planning and control. Asimov's *Robot* and *Foundation* universe encompasses fission associated with interplanetary migration of founder populations, and fusion associated with mergers of humans and Artificial Intelligence.

T14e. Dyson spheres (1960) and Kardashev scales (1964). We may encounter Type i, ii, iii civilizations with planetary, stellar or galactic power sources, or continue our transition toward achieving Type i status. Each step on the Kardashev scale implies massive changes in sociality associated with equally massive changes in access to electrical or other sources of power.

T14f. Banks (1987-2012), and LeGuin (1974). We may experience Banks' *Culture* series in ten volumes that deal explicitly with the spread and evolution across the universe of an anarchistic utopian model of sociality, frequently in contest with less-evolved ways of living. Or we may join Le Guin's *The Dispossessed* as she approaches the same topic from a different direction, with family friend Robert Oppenheimer as the model for a major character.

T14g. Stapledon (1937), Hoyle (1957), Asimov (1972, 1989). We may encounter aliens with radically diverse forms of mind, communication, social organization, gender and sociality. Their heterogeneous impacts on our sociality would be largely, but perhaps not totally, unpredictable.

T14h. Genesis 1:28. On terraforming, "God said ... replenish the earth and subdue it: and have dominion ... over every living thing that moveth upon the earth." We may follow the same devastating concepts and practices in terraforming Mars, the Moon and other satellites that we have followed in terraforming Earth while generating the current mass extinction. This scenario is a highly conservative example of gradualism (possibly emergence) based on moving the same old wine to new bottles.

Hypothetical T14a-h in its many forms invites hypothesis testing, perhaps in the emerging discipline of experimental synthetic biology (Solé 2016a, 2016b). Since some form of T14 is likely to happen, the current situation offers a valuable opportunity for scientists such as Wilson, who has repeatedly expressed concerns about mass extinctions (Wilson 2002), to propose and test hypotheses and methods "in the field".

Given the lack of forethought that has characterized our species in the past, each of these options may occur without adequate prior evaluation of its unintended consequences or prior assessment of its likely social, economic and environmental impacts on Earth or elsewhere. In other words, we have an opportunity to predict and plan for a bright future, but we have a much greater likelihood of screwing up everything. Will the large-scale future simply unfold willy-nilly as it has for the last 4.5 billion years, or will we use our knowledge of mass extinctions, radiations and transitions to observe, describe, predict and control to the best of our ability in keeping with some of the basic tenets of science?

Concerning Asimov's psychohistory, Nobel Prize-winning Princeton economist Paul Krugman (2012:ix) said, "I grew up wanting to be Hari Seldon, using my understanding of the mathematics of human behaviour to save civilisation." But also he noted that "If there eventually is a true, integrated social science, it will still be a science of complex, nonlinear systems – systems that are chaotic in the technical sense, and hence not susceptible to detailed long-run forecasts" (Krugman 2012:xvi). I share the cautious pessimism of both Wilson and Krugman but hope that it may prove to be excessive.

2.2. Social research with globular star clusters.

In Part 1, my starting point at T1 was a lot earlier than Wilson's but it could have been earlier still. Also, the comparative examples that he used were narrowly confined to the social insects, while mine were either a broad range of animals (no plants or fungi) or their predecessors. In other words, both of us began at rather arbitrary starting points. Here I consider a significantly less arbitrary starting point and make a case for its value.

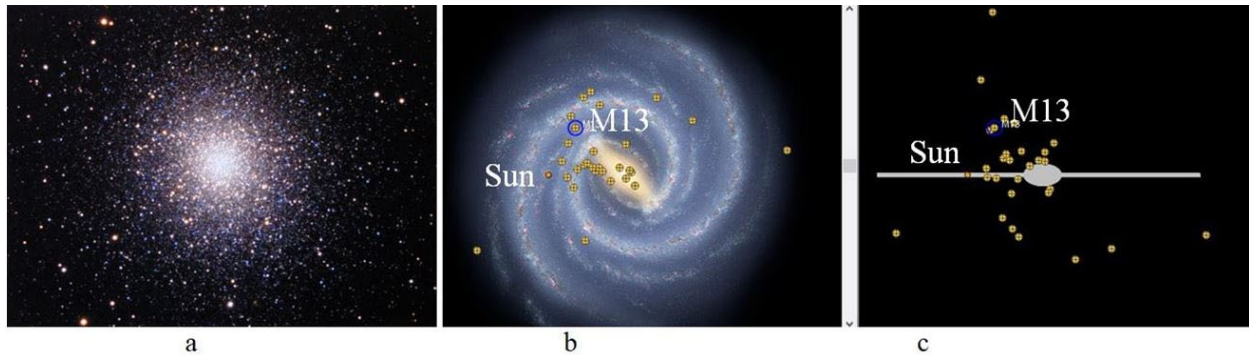
T15. Messier 13 / M13 / NGC 6205. Globular Cluster. Even though transitions in the development of globular star cluster M13 and the evolution of the globular cluster system in the halo of the Milky Way are unknown, I include it in this paper for it raises interesting questions with regard to the bonding that underlies the sociality of all of the other examples in T1 through T13. Specifically, it is presumed to be a non-living entity, while almost everything else discussed in the paper is alive in some sense.

People who prefer transitions associated with really deep origins can ponder the globular cluster M13 (Messier 1758) that appears below and in Table 3, row 3. The Milky Way is a barred spiral galaxy accompanied by more than 150 globular clusters such as M13, and larger galaxies are known to have as many as 13,000 globular clusters each. These clusters are rich, compact, nearly spherical groups of hundreds of thousands or millions of stars, some in the bulge near the center of the galaxy but many in the halo that surrounds the galaxy as a whole.

"Each cluster is a single and specific stellar population, stars born at the same time, in the same place, out of the same material. ... [these] clusters are made up of nearly the oldest – perhaps the very oldest – stars of the universe, and as such they give us an unparalleled opportunity to probe the depths of time that are the remotest to reach" (King 1999:1).

Most of the stars in M13 seem to have formed about 11.66 bya. They are smaller, cooler and chemically simpler than our Sun, and have a much longer life expectancy. The cluster is about 21,000 light years away in the halo above the plane of the galaxy. The stellar population density near its core is Concentration Class V, about average for globular clusters, which means their stellar density is between 100 and 1000 times greater than the density of stars in the neighborhood of our sun. Stellar motions within the cluster are extraordinarily complex. In T15 the processes of dispersal (or its absence) and the resulting pattern of dispersion (or concentration) (Armstrong 1977) that characterize these clusters remain essentially unknown, but *prima facie* evidence in the

Hubble Space Telescope photograph of M13 below attests to extreme sociality (Martinez et al 1999, Ashman and Zepf 1998, Messier 1758).



[T15. M13 globular cluster.

a. Photographed by the Hubble Space Telescope.

b-c. Vertical and horizontal views of the Sun and M13 in relation to the Milky Way as a whole.

Image includes all 29 globular clusters in the Messier catalog.

Graphic generated by Tschumy 2005-2013: "Where Is M13? A Three Dimensional Galactic Atlas."

<http://www.thinkastronomy.com/M13/>.

Bonds of many sorts have provided the underlying tissue (literally and metaphorically) that holds together an organism or society in all of the other cases discussed above. In each case those living entities have been bound to each other at the highest level by the DNA heritage shared by all of life on Earth, at successively lower levels by the processes of speciation, at the lowest level by the descent lines of one's parent or parents. A significantly different kind of bond comes from the physical structures of organisms, including the collocation of organs in multicellular organisms and the specialization of caste structures within freestanding colonies of *Physalia physalis*. Yet other physical, chemical and genetic features underlie the individual and collective activities of the highly communicative social insects, especially in cases of obligate eusociality. Increasingly abstract relational bonds unite monogamous nuclear families among gibbons (Carpenter 1941) and hierarchically organized troops among polygynous hamadryas baboons (Kummer 1968). Humans use their language capacity self-consciously and deliberately to construct genealogies, diverse kinds of kinship terminologies, section and subsection systems, and intricate ways of knowing even in technologically simple societies.

M13 presents what appears to be a remarkable example of sociality with gravity as the bond that holds it together. Perhaps it is analogous to the Portuguese-man-of-war but vastly older, larger and more complex. Furthermore, the extreme age and compactness of globular clusters such as this one provide optimal conditions for life to have emerged, then evolved for about 8 billion years longer than on Earth, and for minimal separation between planets to have fostered intense communications among residents of adjacent planets. Asimov's (1941) short story entitled "Nightfall" is a fine imagining of "human-like" life at a university on a planet deep within a halo cluster such as M13, and serves as a precedent for arguments by DiStefano and Ray (2016) and others for the presence of life and technologically advanced civilizations within halo clusters. In

other words, globular clusters as physical objects, plus the ancient civilizations that may exist within them, make them doubly attractive for research on sociality. Twenty-eight of the 150 known globular clusters in the Milky Way have been identified tentatively as targets for such research (DiStefano and Ray 2016).

Contemplating research on the sociality of globular clusters and their possible inhabitants may not be too far-fetched (Carneiro 2005). In 1974, the plausibility of the argument for life in M13 led Drake (1978:45-70) to send the binary coded Arecibo Interstellar Message (*Wikipedia* 2019. Arecibo message) from the radio telescope in Puerto Rico toward M13 in an early search for extraterrestrial intelligence (SETI; Sagan 1973b, 1978).

Conclusion.

I suggest that all points in Table 3 are important, and that trying to rank order them on an “importance scale” is a useless task that no two people would do the same way. Furthermore, I suggest that by sharpening the focus on *sociality* in that table, rather than retaining the soft and amorphous focus that characterizes Christian’s *Big History*, it becomes easier to quantify frequencies, durations and magnitudes of comparable events spanning the history of life on Earth.

To focus strictly on the human descent line is reminiscent of philosophical and religious traditions spanning the last 10,000 years and may be held safely in abeyance now. Furthermore, focusing on our own descent line misses what may be some of the most fascinating problems in the history of our galaxy. At the very least, these include the remarkable biological complexity of the siphonophores whose oft mentioned 500 million year history has been explored only slightly by members of any academic discipline, and the many puzzles associated with the origin and history of M13 and other globular clusters in the galactic halo. The fact that David Christian’s *Big History* does not mention either siphonophores or globular clusters may be because both lie far beyond the course of human evolution and are misperceived as irrelevant by some authors.

Practical problems make it difficult to design and conduct impact analyses of developments in science and technology such as those outlined in Part 2, but at least seriously considering such matters before the occurrence of disasters like Love Canal, Chernobyl and Facebook would be steps in the right direction. Sagan’s (1973) *Cosmic Connection* was a product of the enthusiasm surrounding the Apollo flights to the Moon and his efforts to influence (i.e., predict and control) long term attitudes toward space travel with that book, with the *Cosmos* television series (Sagan 1980) and with a host of other educational activities seem to have been effective. But his efforts to influence (i.e., predict and control) the short term history of manned space exploration failed abysmally when NASA’s manned space flight program virtually died at the hands of the International Space Station and the Space Shuttle (Dyson 2000:xi, D. Morrison 2000:275-80). We can learn from those events.

Although sociality as “group living”, very broadly and figuratively defined, may be intuitively obvious in the cases discussed above, the bonds that hold those groups together are highly diverse.

Perhaps it is a problem that the stars in M13 and other globular clusters are bound gravitationally instead of genetically, physiologically, chemically or symbolically with kinship terms. But it probably is myopic to rule out gravity bonding, thereby confining sociality research to living entities.

Margulis's (1981) highly successful work on endosymbiosis rests solidly on fusion and cooperation to make sense of relations between prokaryotes and eukaryotes after a century-long effort to understand those matters in terms of conflict and competition had failed (Sapp 1994, 2009; Todes 1989). On the other hand, Wilson's equally successful lifelong research with social insects rests solidly on conflict and competition intrinsic to the Smith-Malthus-Darwin tradition, now supplemented by his emphasis on group selection. Both explanatory strategies tend to converge and yield good science, but relations between cooperation and competition often rest not on solid scientific reasoning and data, but on personal and cultural preferences such as those that have distorted our understanding of the presence or absence of warfare in Aboriginal Australia. Perhaps the real war is between the profoundly unscientific positions of those who secretly advocate nature red in tooth and claw, and those who secretly believe the meek shall inherit the Earth.

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