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11+ things everyone needs to know about microbes

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Well, I made a list. I had written up text justifying everything on this list but I think it is better to just publish the list and then discuss. Any additional suggestions or comments would be welcome.

1. Microbes are small, mostly

2. Microbes are not simple

3. No microbe alive today is ancient

4. There are no good or bad microbes.

4b. Microbes are not here to help us or to hurt us, they are here for themselves

5. We know very little about microbial diversity

5b. We still do not know how many domains, kingdoms, phyla, classes, orders, families, genera, or species of microbes there are.

5c. There are likely hundreds of millions of microbial species on the planet.

6. Microbes can move (using their own power)

7. Attempts to make our world more sterile have massive negative consequences

8. The importance of microbes is both underappreciated and oversold

9. Microbes evolve

10. Microbes are everywhere (mostly) but no one kind of microbe is everywhere (i.e., each microbe has its own range).

11. Microbes are critical to our past, present and future.

Update 1/2/2015 – adding notes for each item

1. Microbes are small, mostly

Yes, I know. Smallness is implied in their name. And there are two things I want to point out here that many people may not be aware of. First, the smallness of microorganisms is a critical part of their biology and, well, why we don't know a lot about their biology. We know lots about birds and trees and

other multicellular creatures because people can see them and observe their biology and biogeography and other properties directly. For microbes, well, that just does not work well.

A second point to make about microbes being small is that, if you group organisms by their evolutionary relatedness (which is the ideal way to group them) we see that there are some organisms that are closely related to microbes, that are in fact not microscopic. This is interesting and important too. For example, consider kelp. They can get very very big. But they are actually not closely related to plants (which they resemble in some ways) but instead are in a group generally known as the "brown algae" and this group is related to diatoms. So – they are certainly NOT microbes, but they are not plants or animals or fungi (the groups people normally think of as having multicellular representatives). Perhaps more confusing, and also more interesting, there are some reasonably big members of groups where virtually all the other members are small (i.e., microscopic). For example, consider Thiomargarita namibiensis a quite big bacterium. This species is in all aspects of its biology a bacterium, but it's larger size does mean that some of the forces that affect it are slightly different than those that affect most single celled bacteria.

I note that some people use the term "microbe" to refer to all taxa that are not plants, animals, or fungi. This seems awkward at best since some of these taxa (e.g. kelp) are not microscopic. I prefer to use microbe to refer to organisms based on their size and then to use the formal group names to refer to evolutionary groupings (e.g., bacteria, archaea, eukaryotes, viruses, etc).

2. Microbes are not simple

Yes, they are small (see above). But many have quite complex processes, structures, behaviors and other features and in general one should never assume things are simple simply because they are small. Consider for example, the relatively recent discovery of a type of adaptive immune system in bacteria and archaea – the CRISPR system. Definitely not simple. Or quorum sensing. Or the sociobiology of Dictyostelium.

3. No microbe alive today is ancient

One sees many many reports of organisms alive today being referred to as "ancient" in relation to their placement in evolutionary trees. Generally, this is done when an organism is in a "deep branching" lineage. That is, if you drew an evolutionary tree of a group of species, this organism's ancestors would have separated from the ancestors of other species a long time ago. Many people for some reason assume that this means that the species on such deep branches have no evolved since they separated off in the evolutionary tree of their group and thus can be viewed as some "relic" or "ancient" taxon. This is just completely wrong. No matter if a taxon is on a deep branch or a recent branch, it continues to evolve and change just as other taxa do.

4. There are no good or bad microbes.

4b. Microbes are not here to help us or to hurt us, they are here for themselves

Not much to add to this other than that the terminology used by humans to refer to microbes frequently includes references to whether they are good or bad. This is bad terminology for a few reasons. First, some organisms may be "bad" to some humans (i.e., they make them sick) while they may be innocuous or even beneficial to others. That is, badness is contingent upon other factors. Second, this terminology is usually used to refer to "species" of microbes as though the whole species is good or bad. And this is almost always a bad idea. Each microbial species comes in many forms – also known as strains. For each species that includes a lot of strains that can make people sick (e.g., *Staphylococcus aureus*), there are strains that are basically harmless. The same is generally true for microbes referred to as "good". One strain might provide a benefit to a host (e.g., as a probiotic) while it might make other people sick.

5. We know very little about microbial diversity

5b. We still do not know how many domains, kingdoms, phyla, classes, orders, families, genera, or species of microbes there are.

5c. There are likely hundreds of millions of microbial species on the planet

Overall, we have just not sampled the full diversity of microbes on the planet at even a remotely deep level. Basically, the best method we have right now to characterize the diversity of types of microbes present in a particular environment is through DNA sequencing. And we have just sampled very few places overall in terms of DNA sequencing technology. For the places we have sampled, we have never, or almost never, saturated the sampling such that we feel like we have characterize all the microbes even in those single samples, let alone across the planet. And then if we add to this how little we know about the biology of different microbes, the absence of knowledge is massive. For example, in 2009 we published a paper on a 1st attempt at building a genomic encyclopedia of ba\ncteria and archaea – to fill in the tree of life with genome sequences (something that stemmed from an NSF Tree of Life grant I had). And though we felt like we were beginning to gain traction on getting genomes of cultured organisms sampled across a decent amount of diversity, most of the lineages of bacteria and archaea on the planet are still as of yet uncultured. And most of the genomic diversity of life is in these lineages. This is why we (well, Tanja Woyke at DOE-JGI with me as a cheerleader) started a project to sequence genomes of novel uncultured lineages – which she called "microbial dark matter" and why a group of us applied for and got a new NSF Geneology of Life grant on the same topic.

What our studies and those of others show is that we know even less about the functional diversity present across the diversity of microbes and that basically, we know only a tiny fraction of a percent of anything about microbial life on the planet.

6. Microbes can move (using their own power)

Many people view microbes as being completely at the whim of their environment in terms of moving around. But this is not so. Microbes swim, crawl, glide, use controlled floating, and do other fascinating types of movements.

7. Attempts to make our world more sterile have massive negative consequences

Not much to say here other than that the obsessive germophobia and overuse of antibiotics is creating some serious problems around the globe. And we really need to stop trying to kill all microbes all the time.

8. The importance of microbes is both underappreciated and oversold

I wrote often about overselling the microbiome and it is a big program (I call it microbiomania). But there is also not enough attention given to the importance of microbes and microbial diversity in many other situations.

9. Microbes evolve

I know. It is obvious to some people. But not to others. And it is critical to appreciate. This relates to the "microbes are not ancient" point above. An appreciation of the rates and patterns of evolution in microbes has big impacts on things like the use of antibiotics and in thinking about microbial ecology an functions in any situation.

10. Microbes are everywhere (mostly) but no one kind of microbe is everywhere (i.e., each microbe has its own range).

Yes, we find microbes in all sorts of places. But it is important to realize that microbes have their geographical patterns and preferences and we do not find all microbes in every place. This is important for issues like conservation biology, agriculture, and human and animal health.

11. Microbes are critical to our past, present and future.