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Rethinking Parts And Wholes

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There seems to be a feeling, a discernment, that our notion of parts and wholes demands a critical reevaluation. The conference from which this volume emerged was not the only one organized recently on this topic. Proceedings from the "*E Pluribus Unum* Conference" are about to appear (Lidgard and Nyhart 2017), the Indian Academy of Science recently published a special issue (Kasbekar and Nanjundiah 2014) on "Individuals and Groups," and a CNRS workshop in Bordeaux has just convened to discuss the dialectic between parts and wholes. This is a topic whose time has come.

Indeed, social, cultural, and political parts and wholes are being dramatically contested at this moment. Economic globalization has turned nation-states into inconvenient boundaries; electronic media enable instantaneous communication across the planet, creating virtual interest-based communities; reproductive technologies have thoroughly altered the definition of the family; industry has fused together science, medicine, and education, such that the boundaries of information and entertainment are difficult to define; and gender and religion, two of the leading boundary conditions in our culture, have become matters of choice. It is no accident that during the past few years there have been so many symposia on part/whole relationships.

And this renegotiation of parts and wholes is especially visible in biology. Biology is, in large part, a study of the relationships between parts and wholes. An individual on one level is a part on another. In the late nineteenth century, embryologist E. B. Wilson (1896, 58) wrote: "There is at present no biological question of greater moment than the means by which the individual cell-activities are co-ordinated, and the organic unity of the body maintained; for upon this question hangs ... our conception of life itself." This question of individuality has taken on renewed prominence in the twenty-first century, as the relationships unifying parts into new wholes are becoming increasingly accessible to study.

Twenty-first-century biology is fundamentally different from twentieth-century biology. It is a biology of relationships rather than entities. The biology of anatomic individualism that had been the basis of genetics, anatomy, physiology, evolution, developmental biology, and immunology has been shown to be, at best, a weak first approximation of

nature (Gilbert et al. 2012; McFall-Ngai et al. 2013). We are neither anatomic nor physiological individuals. More than half the cells in the human body are bacterial, and bacterial products comprise over 30% of our blood metabolites (McFall-Ngai et al. 2013). Our bacterial symbionts play critical roles in constructing our bodies, in maintaining our bodies, and even in regulating some of the cognitive states of our bodies. So we have come to be considered "holobionts," twenty-first-century consortia consisting of the eukaryotic cells plus our persistent microbial communities (Rosenberg et al. 2007; Gilbert et al. 2012).

As a developmental biologist, I have to proclaim that this idea is revolutionary. In the last decade of the twentieth century, a well-respected developmental biologist, Lewis Wolpert (1994), could ask,

> Will the egg be computable? That is, given a total description of the fertilized egg—the total DNA sequence and location of all proteins and RNA—could we predict how the embryo will develop?

By 2001 the answer had been found: No. Indeed, the paper that drew me into the field was Hooper et al. (2001), which showed that bacteria induced normal gene expression, and that if bacteria were absent, the organism had birth defects. Thus, developmental symbiosis was not an exception for organisms like lichens and squids (where research had shown that the lichen developed as a composite of algae and fungi and the light organ of the squid *Euprymna* was formed by interactions between bacteria and squid skin). Rather, developmental symbiosis appears to be universal, even in mammals, where most development occurs in relatively aseptic amniotic environments. Bacteria are an expected part of normative development. This was not the embryology that I had been taught. We had now to deal with the embryology of holobionts, the construction of a functional multilineage organism. In the most literal manner, we follow Donna Haraway's (2008, 3) dictum of "becoming with the other." The holobiont is a very different "body" from the one that was assumed to be monogenomic and a product solely of the fertilized egg. It opens up many new questions that hadn't previously been asked. As a developmental biologist, a scientist who studies how bodies come into existence, I find that the holobiont adds an entirely new dimension to study. There is, for example, the question of how symbionts actually regulate cell differentiation and morphogenesis. In mammals, symbionts are needed for the formation of capillary networks in our gut and are critical for the formation of gut-associated lymphoid tissues. In fish, these bacteria have been shown to be responsible for the normal division of the gut stem cells. We work in collaboration with bacteria in an interspecies ontogeny.

Along with developmental plasticity, developmental symbiosis becomes a major part of the new science of ecological developmental biology ("Eco-Devo"), the study of the relationship between the developing organism and its environment (Gilbert and Epel 2015; Gilbert et al. 2015; Sultan 2015). In an important sense, Eco-Devo continues the tradition of seeing development and environment in terms of a dialectical relationship (Levins and

Lewontin 1985; Odling-Smee et al. 2003). Its emphasis, however, is on the developing organism—an organism that is being created by dialectical relationships, such as those between sperm and egg or between epithelia and mesenchymes.

This notion of holobiont development opens up still further questions. First, if we need bacteria for development, from whence do they come? Mammals acquire most of our microbes as we are born, being colonized by our mother's bacteria as we pass through her mother's reproductive tract. New work suggests that sugars in the mothers' milk given to newborns sustains both the infant mammal *and* the appropriate bacteria (see Arboleya et al. 2016). Many species of insects transport the symbiotic bacteria in the female germline, so they are included in the egg, along with ribosomes and mitochondria. Mammalian childbirth is the passage from one set of symbiotic relations (those with the mother) to a new set of symbiotic relations, those with the microbes (Chiu and Gilbert 2015).

And if this is the case, what is the function of our immune system? The immune system was supposed to destroy that which was not self and to keep us genetically pure. It now seems that we develop with the "other," and that we need that "other." There is now evidence that the immune system recognizes these symbionts and includes them as "self" rather than rejecting them. This would add a new layer to the study of immunology and might even redefine immunology to make the defensive aspect of the immune system a subfunction of a much larger network to regulate symbiotic interactions with the environment (see Gilbert and Tauber 2016; Tauber 2017.)

And what about evolution? If we are constructed as multilineage organisms, what happens to our ideas of "individual selection"? Could it be that teams are being selected? How is competition regulated between these consortia and between the members of the consortia? What prevents cheating by different lineages within the organism? Several papers in this symposium, such as chapter 24, will be addressing these issues.

And what about normal physiological metabolism? There is now evidence that health, even mental health, is a function of co-metabolism between the host and the symbionts. The developmental biology of symbionts leads to the questioning of our basic premises of immunity, health, physiology, and evolution.

So I am grateful for having been given the opportunity to step back a bit and put some of the papers in this volume into some contexts. I see several contexts for developmental symbiosis, in each of which it becomes something else, a different part of a larger whole.

Context 1: Restructuring the Body Politic

The first context is the continued discussion concerning the relationship of the corporeal body to society. In our discussions of collectivities, one cannot help hearing the changes being rung on the theme of the body politic. The body politic metaphor has a long history

and is usually in some way based on the current perceptions of the body given by science. Durkheim (1893/1997), for instance, used this metaphor in his concept of the division of labor, where people contribute to the social body by way of their individual tasks. Moreover, these tasks were envisaged as creating a consensual value of shared common goals, which helps society function in a healthy manner. The notion that there must be internal cooperation if competition with an external enemy is to succeed calls forth the body politic metaphors especially during wartime (Gilbert 1979b).

Symbionts can play havoc with the social notion of a pure body politic. We are definitely not monogenomic individuals (see the Gilbert et al. essay in this volume). Our cells do not share a single lineage. So what are symbionts? If one thinks of an animal organism as an individual, in the classical sense, then the symbionts come into view as *Gastarbeiter*, guest workers who do the work that the stable members of the population won't dirty themselves with. (One might think of such places as Saudi Arabia and Yemen, where certain lineages have citizenship, but most of the population are not citizens, but temporary residents.) If one thinks of an animal in terms of porous borders, then the symbionts can be considered legal resident aliens, like green card–holders in the United States. Only if one thinks of the animal—or any other organism—as a holobiont, where the body is constructed by the immigrant population, are the symbionts full citizens of an evolving and heterogeneous community. Our notions of the body and the body politic mutually reflect shared awareness and anxieties (Sontag 1978; Gilbert 1979b). This volume arises out of a conference in Israel, after all, where the relationship between those recognized as self and those recognized as other takes on a particularly intense existential dimension.

Recently, a metaphor has arisen with formidable implications for our notions of the body and the body politic. Several papers, including a major white paper report published in *Science* (Alivisatos et al. 2015), are concerned with "Harnessing Earth's microbiomes." Such harnessing connotes the domestication of bacteria, putting them to use in the service of humanity, a "tamed" other. It also dovetails, however, with the model of the Plantationocene, the notion of Earth as a plantation, characterized by the massive migrations of genes, crops, livestock, and people to places where they can be regulated and controlled by a ruling minority. The plantation is also a multilineage society, but one that defines itself against the natural and actively combats it (Haraway et al. 2015).

And then there are the very confusing notions of competition and cooperation. These are not "naturally" oppositional categories, despite their continued use in this fashion in both the natural and social sciences. Indeed, the issues of cooperation and competition are culturally dependent. Daniel Brown's (2013) *The Boys in the Boat*, a recent best-seller, takes as one central theme the interplay of competition and cooperation. First one has to "make the team"—a fascinating metaphor: the cooperative team is constructed, made, through competition. But the *competition* is based on which group *cooperates* best.

Different people cooperate better in one group than another. Anyone who has "tried out for a team" knows the intense competition to become part of a cooperating entity. This is also the case in holobionts.

For instance, in the symbiosis of the squid and bacteria that creates the squid's light organ, the squid poisons all other species but one—*Vibrio fischeri*—with which it has evolved to cooperate (McFall-Ngai 2014). In the generation of the microbiota that form the mammalian gut ecosystems, it doesn't appear to be the actual species that are critical, but whether they function well together. Different groups of bacteria can produce different physiological outcomes (Turnbaugh et al. 2009; Patterson and Turnbaugh 2014). Moreover, a species that is a mutualistic symbiont in community can be a pathogen in another (Blaser et al. 2008; Sheh et al. 2013).

Once formed, the team competes against other teams. And it is the team that advances, not the individuals. A football team might have the best goalie in the league, but if the team has no high-scoring offensive forward, this team won't advance. And even as the teams compete, they cooperate to form a higher entity, the league, just as species form a stable ecosystem. From competition comes cooperation; from cooperation comes competition. Both Thomas Huxley and Petr Kropotkin saw this interplay as a major part of evolution. (Huxley emphasized the external competition but saw internal cooperation as being essential for biological and political bodies; Kropotkin emphasized the internal cooperation but saw how these cooperative entities competed against other cooperative entities; see Gilbert 1979a). "Making the team" becomes another metaphor for society. Symbiosis becomes recognized as a major player in the strategies that support life on this planet. The notion of "becoming with the other" has to be taken literally and has to become part of an evolutionary biology that was previously based on a notion of the "war of each against all" (Gilbert and Epel 2015). If we are to model our conceptions of society on the structure of our organisms, we have a lot of new vocabulary to invent.

Obviously, defining self and nonself is a complicated process, and it is one that we are just beginning to understand. Latour (2004) and Stengers (2005) conceive of the ecosystem as a polity in which all constituents participate in a constant negotiation of belonging and elimination. This model may apply to our bodies, as well. According to immune network theory, the immunocompetent cells make proteins capable of recognizing every shape in the biological universe. Thus, holobionts aren't totally foreign because there is actually a recognizable image of their molecular surfaces already present within the body. Moreover, the immunocompetent cells that recognize these shapes are, by these very abilities of recognition, not normal members of the body. To recognize these shapes, they have had to alter their genomic DNA. The DNA of immune cells that sense the other is not the DNA characterizing the other cells of the body. The immune cells are indeed "diplomats" (in Latour's sense) since they can negotiate *because* they are not identical with their source. Metaphorically, they are the agents that see the "big picture" rather than narrower partisan views. "Diplomacy," writes Stengers (2005, 93), "is a

technology of belonging," which, especially in the case of the holobiont, determines who "we" are.

Latour (2004, 217, emphasis in the original) writes:

> The external enemy, for good reason, terrifies those who imagine that what defines their essence is going to be torn away; barbarians frighten barbarians. But the enemy that the diplomat accompanies does not put the collective in danger in the same way, since he is the bearer of a peace proposal that goes far beyond mere compromise: "Thanks to you, we are going to understand the difference between our essential requirements and their temporary expressions." Finally, we are going to know what we want and what this "we" is that says it is endowed with a will. The diplomat recalls *that no one who does not lend himself to this work of negotiation can invoke the unity of the collective.*

The study of how the immune system negotiates our holobiotic selfhood will be one of the most fascinating new research projects brought into existence by our new awareness of our multilineage origins (see Tauber, this volume). It has the potential to change the ways we think about self, evolution, and the other.

Personally, I like the fact that the Hebrew word for life is the plural "*Chaim*." *L'Chaim*—to life/lives. One does not live alone either biologically or socially. Similarly, "*Shalom*" is all about the relationships of parts and wholes. It is not merely the absence of war. It involves the creative interaction of the parts for mutual flourishing and justice. War is easy. One has an other to fight. It is easy to cooperate against an other. Shalom is difficult. One must perceive and actively strive for a good greater than one's own immediate self-interests. This needs diplomats.

Context 2: Virtual Communities

Main Street and mall, agora and forum, are all things of the past. The "neighborhood" that geographically defined a community is hard to maintain when everything from books to fishing bait can be ordered online. One need not meet neighbors or visit the local stores when Amazon or Alibaba delivers directly to your home. Communities are now made online, and people are more likely to find the love of their life in a chat room than in a library or market. One no longer needs to physically meet someone to become their close friend, rival, or teammate. I have written several papers through email collaborations and have never met some coauthors (even on a paper of just two people).

In creating this book, we have used this capacity of the Internet to sustain the community that we instigated by a physical meeting in Israel. We took away from that meeting certain ideas and then used email to produce another type of body, a "body of knowledge." That is what this book is. It is a corpus, a body, of knowledge. The various works here, from various disciplines, are being tied together, ligated into a common volume. This is an act of taking parts and making a new whole.

The resulting "body of knowledge" is found not only in this book, but in communities that became organized during our physical meeting. For instance, Eugene Rosenberg, Ilana Zilber-Rosenberg, and myself presented data on the holobiont as an organized collective that was, itself, a level of evolutionary selection. Our perspectives, however, came from microbiology and developmental biology. What we lacked was grounding in evolutionary theory. This was provided by our interactions with Joan Roughgarden and Elisabeth Lloyd. They were able to individually consider the holobiont as a possible unit of selections and have papers in this volume concerning this. However, we remained a community and have written an integrated paper that is different than the sum of its parts. We are at present on the tenth iteration of our paper, which has become an educational endeavor for all concerned.

Context 3: Philosophical Speculations on Dialectics

As mentioned above, another context of this conference is in the philosophical discussions of dialectics. Levins and Lewontin's (1985) *The Dialectical Biologist* was published 30 years ago, and that book provides one of the most important and explicit statements of part/whole relationships in biology and society. It was here (Levins and Lewontin, 1985, 3) that biologists (few of whom read Kant, Hegel, or Engels) were taught that "Parts and wholes evolve in consequence of their relationship, and the relationship, itself, evolves ... that one thing cannot exist without the other and that one acquires its properties from its relation to the other, that the properties of both evolve as a consequence of their interpenetration." It was also here that the concept of niche construction was introduced, and this has played an important conceptual role in notions of developmental symbiosis (see Chiu and Gilbert 2015; Sultan 2015).

In dialectic, subject and context each have agency, and symbiosis refers to both pathogenic (harmful) and mutualistic (beneficial) relationships. A microbe such as *Helicobacter pylori* can be a disease-preventing mutualist in one person and a cancer-inducing pathogen in another (Atherton and Blaser 2009; Yang et al. 2016). A mutualistic symbiont can also become a pathogen if the immune system is compromised. This occurs both in the individual (as seen with opportunistic infections in AIDS) and also at the level of society. European settlers came to the New World as holobionts, both hominids and microbes. For the Europeans, who had experienced and survived these microbes from birth, their bacteria and viruses were relatively harmless. However, the indigenous peoples of these continents had no immunity to the agents of smallpox, rubella, and influenza (Crosby 1972; McNeill 1976). The conquest of the New World was accomplished primarily through the European microbes becoming symbionts of the Europeans and pathogens of the Amerindians.

It is interesting to view our symposium and volume as validation and vindication of these dialectical relationships. What had been the idea of a dialectic of life, grounded in

philosophy and evidenced from ecology, has become an overwhelmingly important and central principle with data from all areas of biology and sociology. Like the notion of symbiosis, what had been peripheral three decades ago has now become central. Of course, this isn't universally recognized as being the case. But we should take William Gibson's 1999 quotation to heart: "The future is already here. It's just not evenly distributed yet" (quoted in Kennedy 2012).

Footnote: Back to Padan-Aram

An ironic footnote: We've been looking at society from the standpoint of the big guy. But most of our cells are microbes. From their point of view, we are a source of niches. This shows the inadequacy of the "extended phenotype" approach, as each holobiont becomes the extended phenotype of billions of organisms. Moreover, taking an "inclusive fitness" perspective from the symbionts' standpoint, successful bacteria have evolved to expand its population by making more niches. In other words, they want us to reproduce. There exist parasites that are able to change the behaviors of their hosts to make them more amorous and so have more offspring (Adamo 2014; Adamo et al. 2014). So maybe symbionts can do the same. We also know that symbionts can communicate with hosts to promote fertility, and we also know that symbionts can alter sexual development to promote the production of females (Pontier and Schweisguth 2015; see Gilbert and Epel 2015). So, in female mammals, symbionts would promote reproduction—make more niches for their progeny. (Maybe they would erase the memories of previous pregnancies and deliveries in mammals.) In males (where the symbionts from the males' mother are not propagated), the symbionts would benefit most if the males mated with relatives of their mother. This is the Padan-Aram strategy of the Biblical patriarchs: Isaac marries a relative from Padan-Aram and then tells his son Jacob, to return there to find a wife among his mother's family. The lineage may be patriarchal; but the symbionts are those of the matriarch's lineage.

References

Adamo, S. A. (2014). Parasitic aphrodisiacs: Manipulation of the hosts' behavioral defenses by sexually transmitted parasites. *Journal of Experimental Biology, 54*, 159–165.

Adamo, S. A., Kovalko, I., Easy, R. H., & Stoltz, D. (2014). A viral aphrodisiac in the cricket *Gryllus texensis*. *Journal of Experimental Biology, 217*, 1970–1976.

Alivisatos, A. P., & the Unified Microbiome Initiative, et al. (2015). Harnessing Earth's microbiomes. *Science, 350*, 507–508.

Arboleya, S., Stanton, C., Ryan, C. A., Dempsey, E., & Ross, P. R. (2016). Bosom buddies: The symbiotic relationship between infants and *Bifidobacterium longum* ssp. l*ongum* and ssp. *infantis*: Genetic and probiotic features. *Annual Review of Food Science and Technology, 7*, 1–21.

Atherton, J. C., & Blaser, M. J. (2009). Coadaptation of *Helicobacter pylori* and humans: Ancient history, modern implications. *Journal of Clinical Investigation, 119*, 2475–2487.

Blaser, M. J., Chen, Y., & Reibman, J. (2008). Does *Helicobacter pylori* protect against asthma and allergy? *Gut, 57*, 561–567.

Brown, D. J. (2013). *The Boys in the Boat: Nine Americans and Their Epic Quest for Gold at the 1936 Berlin Olympics*. New York: Penguin Books.

Chiu, L., & Gilbert, S. F. (2015). The birth of the holobiont: Multi-species birthing through mutual scaffolding and niche construction. *Biosemiotics, 8*, 191–210.

Crosby, A. W. (1972). *The Columbian Exchange: Biological and Cultural Consequences of 1492*. Santa Barbara: Praeger.

Durkheim, E. (1997). *The Division of Labor in Society* (W. D. Halls, Trans.). New York: Free Press. (Original work published 1893)

Gilbert, S. F. (1979a). Altruism and other unnatural acts: T. H. Huxley on nature, man, and society. *Perspectives in Biology and Medicine, 22*, 346–358.

Gilbert, S. F. (1979b). The metaphorical structuring of social perceptions. *Soundings, 62*, 166–186.

Gilbert, S. F., Bosch, T. C. G., & Ledón-Rettig, C. (2015). Eco-evo-devo: Developmental symbiosis and developmental plasticity as evolutionary agents. *Nature Reviews. Genetics, 16*, 611–622.

Gilbert, S. F., & Epel, D. (2015). *Ecological Developmental Biology: The Environmental Regulation of Development, Health, and Evolution*. Sunderland, MA: Sinauer.

Gilbert, S. F., Sapp, J., & Tauber, A. I. (2012). A symbiotic view of life: We have never been individuals. *Quarterly Review of Biology, 87*, 325–341.

Gilbert, S. F., & Tauber, A. I. (2016). Rethininking individuality: The dialectics of the holobiont. *Biology & Philosophy, 31*, 839–853.

Haraway, D. H. (2008). *When Species Meet*. Minneapolis: University of Minnesota Press.

Haraway, D., Ishikawa, N., Gilbert, S. F., Olwig, K., Tsing, A. L., & Bubant, N. (2015). Anthropologists are talking: About the Anthropocene. *Ethnos*. doi:10.1080/00141844.2015.1105838.

Hooper, L. V., Wong, M. H., Thelin, A., Hansson, L., Falk, P. G., & Gordon, J. I. (2001). Molecular analysis of commensal host-microbial relationships in the intestine. *Science, 291*, 881–884.

Kasbekar, D. P., & Nanjundiah, V. (Eds.). (2014). Special issue: Individuals and groups. *Journal of Biosciences, 39*(2).

Kennedy, P. (2012). William Gibson's future is now. *The New York Times*. January 13, 2012. http://www.nytimes.com/2012/01/15/books/review/distrust-that-particular-flavor-by-william-gibson-book-review.html.

Latour, B. (2004). *Politics of Nature: How to Bring the Sciences into Democracy* (C. Porter, Trans.). Cambridge, MA: Harvard University Press.

Levins, R., & Lewontin, R. (1985). *The Dialectical Biologist*. Cambridge, MA: Harvard University Press.

Lidgard, S. S., & Nyhart, L. K. (2017). *Biological Individuality: Integrating Scientific, Philosophical, and Historical Perspectives*. Chicago: University of Chicago Press.

McFall-Ngai, M. J. (2014). The importance of microbes in animal development: Lessons from the squid–vibrio symbiosis. *Annual Review of Microbiology, 68*, 177–194.

McFall-Ngai, M., Hadfield, M. G., Bosch, T. C., Carey, H. V., Domazet-Loso, T., Douglas, A. E., et al. (2013). Animals in a bacterial world: A new imperative for the life sciences. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 3229–3236.

McNeill, W. H. (1976). *Plagues and Peoples*. New York: Anchor Books.

Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2003). *Niche Construction: The Neglected Process in Evolution*. Princeton, NJ: Princeton University Press.

Patterson, A. D., & Turnbaugh, P. J. (2014). Microbial determinants of biochemical individuality and their impact on toxicology and pharmacology. *Cell Metabolism, 20*, 761–768.

Pontier, S. M., & Schweisguth, F. A. (2015). *Wolbachia*-sensitive communication between male and female pupae controls gamete compatibility in *Drosophila. Current Biology, 25*, 2339–2348.

Rosenberg, E., Koren, O., Reshef, L., Efrony, R., & Zilber-Rosenberg, I. (2007). The role of microorganisms in coral health, disease and evolution. *Nature Reviews. Microbiology, 5*, 355–362.

Sheh, A., Chaturvedi, R., Merrell, D. S., Correa, P., Wilson, K. T., & Fox, J. G. (2013). Phylogeographic origin of *Helicobacter pylori* determines host-adaptive responses upon coculture with gastric epithelial cells. *Infection and Immunity, 8*, 2468–2477.

Sontag, S. (1978). *Illness as Metaphor*. New York: Farrar, Straus & Giroux.

Stengers, I. (2005). Introductory notes on an ecology of practices. *Critical Studies Review, 11*, 183–196.

Sultan, S. (2015). *Organism and Environment: Ecological Development, Niche Construction, and Adaptation*. Oxford, UK: Oxford University Press.

Tauber, A. I. (2017). *Immunity: The Evolution of an Idea*. New York: Oxford University Press.

Turnbaugh, P. J., et al. (2009). A core gut microbiome in obese and lean twins. *Nature, 457*, 480–484.

Wilson, E. B. (1896). *The Cell in Development and Inheritance*. New York: Columbia University Press.

Wolpert, L. (1994). Do we understand development? *Science, 266*, 571–572.

Yang, I., Woltemate, S., Piazuelo, M. B., Bravo, L. E., Yepez, M. C., Romero-Gallo, J., et al. (2016). Different gastric microbiota compositions in two human populations with high and low gastric cancer risk in Columbia. *Scientific Reports, 6*, 18594. doi:10.1038/srep18594.