TRANSMISSION OF DISEASE AND KNOWLEDGE

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I grew up along the Saar River in Germany, alongside the activities of a vineyard and winery. I went to high school in nearby Trier, where I received my Abitur from the same school where Karl Marx graduated some 14 decades earlier. For undergraduate study in biology, I went to Munich. In between, I did an exchange year at the University of South Alabama and began to develop an interest in evolutionary biology. My Ph.D. is from the University of Basel in Switzerland. After postdoctoral fellowships in Moscow, Gamboa (Panama), Oxford, and London, I returned to Basel as an Assistant Professor, and spent five years working in the former study of Friedrich Nietzsche. After becoming a Professor in 2001 at Fribourg University (Switzerland), I moved back to Basel in 2004. Today, I do most of my research there in my laboratory at the Zoological Institute, though I also spend about six weeks a year in Finland, doing ecological fieldwork on the Skerry islands of the Baltic Sea. My main research interest lies in the evolution of infectious diseases and the coevolution of hosts and parasites. – Address: Zoologisches Institut, Universität Basel, Vesalgasse 1, 4051 Basel, Switzerland. E-mail: dieter.ebert@unibas.ch

A year at the Wissenschaftskolleg gave me time to reflect on the spaces where I have studied, worked and grown up in new ways, through conversations with scholars who read and teach Marx, Nietzsche and Darwin as sociologists, historians, anthropologists and literary scholars. This occasion to report on my year at the Wiko has me wanting to combine two aspects of my life and work at this unusual institution. These dimensions are conceptually related: both concern transmission of information from one individual to another. But they differ in the "what" that is transmitted. I consider transmission from an

evolutionary angle. As an evolutionary biologist, I have long had a deep interest in understanding the mechanisms, causes and consequences of transmission and the changes in the information or knowledge transmitted. Both happen in and with time, and both have important impacts on the evolution of organisms and on culture. The first kind of transmission is genetic information transfer: in the context of my research, specifically the transmission of small organisms among hosts. I call these organisms symbionts, a collective term for parasites, pathogens and mutualists. Transmission, as conceptualised within a context of cultural evolution, is the transfer of, usually, spoken and written information or knowledge among people.

First, I will consider the flow of information among individuals and groups. Naturally, we are aware of this kind of transmission among humans, but the concept also applies to communication among animals. Humans use language in writing and speech, but similar means of conveying information are known among animals, whether through vibrations, chemical communication or symbols. Flows of non-genetic information among individuals and groups are the basis of cultural evolution. Thus, cultural evolution refers to kinds of traits that develop and persist. Traits may include habits and technological know-how, such as the knowledge used to produce stone tools, compose music or communicate with words and languages, in poetry and song. Traits persist because the information that was necessary for these traits to come about in the first place is transmitted among the members of the population and to succeeding generations. Cultural traits may change over time, as some parts are lost or others are added. Change may result from "faulty transmission" or, alternatively, from innovation. Interestingly, the means by which information is transmitted – mostly words – is itself a product of cultural evolution; this is certainly the case in humans, even if it is not necessarily the case in animals. Our languages are means of transportation for information, for knowledge; and our languages persist (with changes) because of transmission. Mothers usually lead in teaching the next generation to speak their language. A child who grows up without learning a language will be unable to communicate. Cultural evolution critically hinges on transmission. Products of cultural evolution are not in our genes.

Darwinian evolution is characterized by what evolutionary biologists term vertical inheritance. Genes are passed from parents to offspring. In contrast, cultural evolution is based on both vertical (parent to offspring) and horizontal transfer of information. Horizontal transmission is among unrelated persons, and the admission of this kind of non-genetic, non-kin transmission is a radical extension of the Darwinian model of

evolution. Since evolutionary biologists first began considering horizontal transmission, it has opened our research to the possibility that traits may spread much faster than Darwin's followers had previously thought. Not unlike the way a new fashion in clothing or music may spread with lightening speed, horizontal and cultural transmissions are not tied to or limited by the slow temporality of reproductive succession.

Contrary to anecdote and myth, science does not progress because a lone researcher chooses the life of an isolated hermit and then reappears after decades of contemplation with startling solutions to vexing problems. Rather, scientists of all sorts communicate with each other and make use of each other's scientific knowledge. Means of dissemination include books and articles, the Internet and e-mail. Active communication is an essential part of scientific work, but certainly not a signature of modern times. Communication has been driving ideas and accelerating their development since ancient times. We know that Berlin's Alexander von Humboldt wrote more than 13,000 letters in his lifetime to more than 2,700 different persons. Each day, Charles Darwin devoted a time slot for his letter writing, with an estimated production of more than 15,000 in all.

The Wissenschaftskolleg is a communication hotspot. Exchange of information and knowledge is omnipresent, and intellectual debate and learning from others is at the very core of the Wiko mission. Fellows from diverse places in our geographic, cultural and academic worlds meet and exchange ideas, teach each other languages, bring their cultures and ideas to Berlin and take bits of Berlin and Wiko-culture back home with them. What was different from my average academic year as a biologist was that I was in a setting at the Wissenschaftskolleg where I no longer chose the people I communicated with on a regular basis. The cast of characters for our conversations and debates was all set, by others, by the time I arrived in early October 2010. All we had to do was begin our year's big experiment, an experiment in the transmission of knowledge, information and experience. For me it was the first time that, over an extended period of time, I was hearing, listening to and asking questions in fields I had hardly had contact with before. How often in my life would I have a chance to sit for hours at a dinner table with renowned experts in fields like ancient Arabic literature, philosophy, African history, international law, Greek art and French cooking, to name just a few. Most eye-opening for me was realizing what very different concepts we use and apply in our different fields, what dissimilar methods we use to produce knowledge and especially what methods and concepts are (almost) forbidden and why. The prison of my own mind set, of my own intellectual and scientific formation, became more apparent to me than before.

Now I want to turn to another form of transmission, a form I work with every day as a scientist. This other kind is the transmission of symbionts, mostly the transmission of disease agents. The intricacies of their transmission were at the centre of my research at the Wissenschaftskolleg. I was refining concepts for studying the spread of symbionts in host populations, e.g. the spread of infectious disease. In this kind of transmission, an organism – the symbiont – is the entity that moves, that is transmitted. The information – the entirety of its genetic information – is encoded in its genome. Interactions with the infected host, to a large extent, depend on this genetic information. Traditionally, scientists have classified transmission of symbionts as being either vertical or horizontal, that is, from a parent – (usually the mother) – to offspring or passed among unrelated hosts, respectively. What epidemiologists have rarely considered is that symbionts may be transmitted in both ways, both vertically and horizontally, a capacity I call "mixed-mode transmission". My Wissenschaftskolleg project was to articulate, at a conceptual level, an understanding of the biology, epidemiology and evolution of symbionts that make use of mixed-mode transmission. One of the major points that I worked out is this: contrary to common scientific belief, symbionts using exclusively vertical or exclusively horizontal transmission are, in fact, exceedingly rare. Most symbionts combine horizontal and vertical transmission, which is not unlike people transmitting ideas and culture both to kin and to strangers. Symbionts with mixed-mode transmission comprise a large part of the human, animal and plant microbiota, i.e. the community of microbes that accompany each individual throughout his or her life. Each human being carries about 3,000 species of bacteria at any moment, whether in the gut or on the surface of the skin. Some of them are harmful, others are beneficial to us. These bacteria are transmitted from mother to offspring (thus, vertically), but also they are transmitted when two unrelated people meet, for example, when they shake hands (an example of horizontal transmission). Most bacterial species transmit sometimes in one way, sometimes in the other. Mixed-mode transmission allows much higher rates of spread than either of the single modes would do. Scientific understanding of the causes and consequences of such mixed-mode transmission still lags far behind understanding of those symbionts using either vertical or horizontal transmission exclusively.

Working through the literature on symbiont transmission, I had to read articles from many different fields, parasitology, microbiology, virology, botany and epidemiology among them. The pleasure of learning so much from such diverse fields at times came to a halt, interrupted by my frustration over and need to reconcile the divergent terminology

used in these fields without a common language. Sometimes one term came into use for different things; sometimes the same thing had different names. As I reconciled these differences, I managed to extract a number of new insights and in some cases came to conclusions that run contrary to common convention. I will share just a few of these here. One question I asked was this: does it make a difference if a symbiont is exclusively transmitted in one mode? Or does a little bit of additional transmission by the second mode have strong consequences for the system in question? The answer surprised me: even a small bit of a secondary mode of transmission makes a large difference for the system. For example, a virus that causes disease in lettuce plants will go extinct if a quite small amount of mother-offspring transmission does not accompany its routine horizontal transmission. Such minority modes of transmission may easily escape the attention of observers, leading to wrong conclusions about the epidemiology of a system or disease. Another aspect that also flies in the face of conventional wisdom is the relative rates with which vertical and horizontal transmission occur. Scientists have tended to assume that the more one mode of transmission exists, the less the other is present. They have spoken of this relativity as a "trade-off". My work shows rather that in most cases, more of one mode goes hand-in-hand with more of the other mode. Thus, symbionts with a high propensity to transmit horizontally are also easily transmitted vertically. Finally, interesting aspects are discovered by examining what happens when a host becomes infected with two or more different strains of a symbiont. Such symbionts sit as if in the same boat and have to make the best out of their situation. The tragedy of the commons arises, i.e. how to share a common good, the host. The symbiont able to monopolize a larger share of host resources will have an advantage over other symbionts without the same capacity. Hosts suffer more from such competition within hosts. As a result, it is in a host's interest to avoid multiple infections, and the easiest way of doing so is by allowing only vertical transmission and from one source, usually the mother. In this way, all symbionts within the offspring will be the same, and no competition will arise. The result may be a peaceful world, but not necessarily the place where innovation will arise. My hope is that these findings, taken together, will prove useful not only in fields like public health, medicine and epidemiology, but also in agriculture, ecology and evolution.

But where are the connections between symbiont transmission and information transmission? The connections become visible if we ask about the driving forces behind progress or change. In the evolutionary biology of parasites and pathogens, it is commonly believed that multiple infections, competition and recombination play key roles in

driving adaptive change. Multiple infections bring in genes from different parasite lines. These lines are tested in direct comparison (or competition), and these lines may also be mixed and recombined, resulting in new gene combinations. Selection can act on the newly created variation, separating offspring with better performance from those not doing so well. Overall, parasites will become more effective. Even so, such improvements may be bad for the host. By contrast, if symbiont transmission only works from mothers to offspring, evolution will proceed slowly and thus be less likely to result in novelty – at least any time soon.

These issues of innovation and speed are also true for advances in ideas. Input from multiple sources will lead to new ideas developing more quickly, to testing some ideas against competing ideas and to recombining parts and building others, producing new ways of thinking in the process. At the Wissenschaftskolleg, the exchange of ideas, concepts, cultural dispositions and personal histories among Fellows produces an unending flow of new combinations, ideas and themes. It seems to me that this is the very nature of the Wissenschaftskolleg and that the institution, wittingly or not, capitalizes on these mixed modes of communication (transmission) and sharing. Fellows with different backgrounds live and talk together. As in biological evolution, some innovations are playful and momentary, while other combinations and mixtures are more significant and enduring. Of course, neither in evolution nor at the Wissenschaftskolleg can the success of such an enterprise be predicted. But on the average, horizontal transfer and the mixing of lines will more often result in innovation and novelty than vertical transmission alone.

During my months at the Wissenschaftskolleg, I often felt like I was becoming multiply infected with ideas stemming from diverse sources, and the infectious process became part of daily life, often mixed with jokes and funny stories. Furthermore, I took more inspiration from reading books outside my conventional field and territory than in the years before. I also came away with ideas for writing books in new ways, one of which I am following up on now in Basel.