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> "If the germ theory is the idea that the presence of bad species can make you sick, the growing sense seems to be that the opposite can also be true."

Letting Biodiversity Get under Our Skin

By Rob Dunn

Some aspects of dirty living can be healthy. A new study posits that the decline of plant and animal diversity in cities may be linked to the recent surge of allergies and other chronic inflammatory diseases.

SUMMARY QUESTIONS

worksheet available online

1. What are the three "global megatrends" described by the author? (answer: 1. People moving from rural homes to cities, 2. Loss of biodiversity, 3. Rising prevalence of allergies and chronic inflammatory diseases in urban populations in developed countries.)

2. List some examples given for allergies and chronic inflammatory diseases.

3. What is germ theory? What is the opposite theory described in the article? (answer: Germ theory = presence of bad species can make you sick. Opposite theory = absence of good species can make you sick.)

4. What is the hygiene hypothesis? (answer: The immune system needs exposure to biodiverse bacteria in order to work properly. Urbanites are too removed from microbial nature for their immune system to develop properly.)

What's Inside:

5. Describe the study design, methods, and major findings of Hanski's research group. (answer: 118 adolescents within a 100x150 km area, some houses by chance in city, other in the woods or on farms. Data collection included: blood drawn from the adolescents screened for evidence of allergies, forearms swabbed and species genetically IDed, collection and ID of every species of plant around subjects' houses. Findings showed that higher native-plant species diversity was associated with altered microbial composition on the skin samples, which led to lower risk of allergies. The microbe family, gammaproteobacteria, seemed to be especially important.)

6. How does the author describe the functioning of our immune system? (answer: Our immune system is our "inner-taxonomist," not just our "attack dog." Its primary role is to determine which species are good, bad, or innocuous. The attack is secondary. If we aren't exposed to a large enough diversity of microbes, our immune system doesn't 'learn' well enough, and will not be able to tell good from bad as well, leading to allergies.)

DISCUSSION QUESTIONS

worksheet available online

1. After reading the article, are you convinced of an answer to the main question of the article: "Could our distance from nature and our chronic immunological discontent be related?"

2. Discuss the dynamics of germ theory versus the opposite scenario. Do you think that one is more accurate than the other? Could both processes be operating at the same time? What other system(s) in the body have a similar "biodiversity" requirement for healthy operation? (HINT: digestive system! Why is probiotic yogurt good for you? What does it mean when probiotics say "live cultures"? Is there really a difference between regular yogurt and the fancy probiotic stuff?)

3. What is your reaction to the figure from the New England Journal of Medicine? Do you or your immediate family have allergies or a chronic inflammatory disease? Ask your parents or grandparents what they remember about their peers having these types of symptoms. Where did you grow up compared with your grandparents? Do you think that your childhood home has something to do with your immune system responses? What alternate explanations can you come up with for explaining the rise in allergies? (HINT: Do you think these trends could be due to increasing awareness or reporting rather than an increase in symptoms?)

> "We are good at killing species around our houses and on our bodies, but far less practiced at cultivating them."

BUILD YOUR OWN GLOSSARY

- germ theory
- hygiene hypothesis
- atopy
- biodiversity

4. After reading the article, what is your reaction to this commercial? *http://www.youtube.com/watch?v=XWVA7epfiRk* and this one *http://www.youtube.com/watch?feature=fvwp&NR=1&v=LK6ejs1WmWg*. What are we cleaning/killing with household disinfectant?

5. How would you define "dirty"? What is your reaction to the author's statements: "Yet, as complex as the connections might be, consensus has begun to emerge that some aspect of "dirty" living is good." "We are good at killing species around our houses and on our bodies, but far less practiced at cultivating them." How could we bring a little dirtiness into our lives? (HINT: should we be planting gardens inside hospitals to combat viruses or fungi? Would house plants help?)

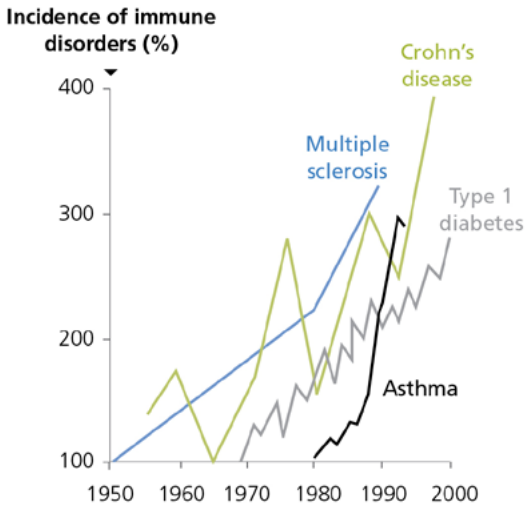
6. What is your reaction to: "[W]e kill the life most susceptible to our weapons. In their place grows a more depauperate and resistant wildness—nature despite us, not for us—a jungle of potentially dangerous weeds. We are reducing diversity in our daily lives, even on our bodies, in exactly the same way that we are reducing it in the world. We manage our own flesh as we manage the earth."

7. What are the three proposed mechanisms explaining why the body needs to experience microbial diversity in order to have a healthy immune system? How does a reduction in microbial diversity in our lives potentially lead to increasing allergies?

8. What might Hanski's findings mean for the evaluation of ecosystem services and the ethics of maintaining biodiversity? Should we lessen our focus on the aesthetic role of nature because it's difficult to quantify its benefits for our mental health, and instead focus on things like pest control, clean water and air, crop pollination, and now perhaps our physical health? What are the benefits to focusing on dollar amounts of ecosystem services? Are there drawbacks or potential problems in lessening our focus on aesthetics or mental health benefits from nature?

ADVANCED ACTIVITIES

1. **Dive into the Research:** Find the numbers to support or refute the author's claims of increasing incidence of allergies and chronic inflammatory diseases. Read the Bach (2002) paper. Look up David Strachan's work (St. George's University of London) on farm versus city kids. Look up the research on how parasitic worms and allergies are inversely related. Look up the study on dog-households, bacteria, and pregnancy-related allergies. Look up the laboratory mouse study showing skin bacteria linked with immune system development.



Bach, J.F. 2002. *New England Journal of Medicine* doi.full/10.1056/NEJMra020100.

2. **Scientific Study Design in Complex Systems:** Read the Hanski, et al. (2012) research paper described in the story. What confounding factors make it hard to link diversity of life surrounding a person with their immunological status? What was so elegant about the study design? How did Hanski control for confounding factors? What sampling methods did the researchers use? What were the drawbacks of Hanski's design? Design your own research study to address the broad research question. Can you design a study to not only look at correlation, but also look at causality (e.g. alternative hypotheses being the three proposed mechanisms by which microbial diversity is linked to reduction in allergies.) (HINT: maybe indoor household plants?)

3. **Exploring Theories in Human Health:** There are a number of other human health ailments listed in the article that are reportedly linked to a decrease in our proximity to natural diversity. Choose one of the listed health theories and find out what research has been done on the topic. Break the class into discussion groups or debate teams around each topic. Present research findings and conclusions to the group.

4. **Metadata Analysis of Biodiversity and Resilience:** What is a metadata analysis? Read one or two examples. Brainstorm as a group what types of questions you'd like to ask of a metadata analysis, and what data you'd pull out from articles to answer those questions. Decide how you will search for articles (choose parameters to restrict your search, pick databases). Find research articles (from community ecology, soil ecology, human physiology, and more) and pull out the target data. Summarize the details of the study system, study design (e.g. is it an experimental study or observational study), and conclusions drawn. Compile your group's data into a new figure or table. (ADVANCED: are there other comparable metadata analysis articles out there? If not, publish!)

5. **Science in the Moment:** Find a question pertaining to microbial communities and human health that interests you and look up the current research (places to start: pregnancy, pets/plants in the home, a specific disease/disorder). Find out what the author means by: "[I]t's not yet been established whether we are missing interactions with lots of microbes, lots of kinds of microbes, or something else."

TRUE STORY: A women's synchronized swim team was tested for foot fungus. All women had mild cases of foot fungus except for one woman who had none. The researchers questioned her about her hygienic habits and soon discovered that she was the only woman who didn't wear rubber slippers in the locker room showers. There were other characteristics of this woman that might influence the outcome— e.g. while all women

Further Reading:
Author Rob Dunn is a biologist in the Department of Biology at North Carolina State. His research has strong emphasis on citizen science and biodiversity in the home. His book, *The Wild Life of Our Bodies*, explores our interaction with other species and impacts on human health and well-being. His website, *yourwildlife.org*, is a clearing-house for information and ongoing research projects with citizen science studying a wide variety of questions, including bellybutton microbial diversity!

were raised in cities, the woman without foot fungus was from Mexico City, whereas the rest of the women were from a US Midwestern city.)

Do you find this story a compelling argument in agreement with the article? Can you find any scientific evidence to substantiate this anecdotal story?

6. **Science Communication and Shifting Public Attitudes:** The recent public appreciation of gut flora and a corresponding boom in commercial products (pro-biotic pills, pro-biotic yogurt, etc.) is an amazing example of shifting public attitudes toward science-based healthy living. Examine some of the campaign materials behind these shifts in attitudes. Were there sources of resistance to the probiotic campaign (e.g. arguments that a "clean" digestive tract was better? Icky-ness?) The author writes, "To ecologists such as Hanski, the interdependence of species is self-evident; the normal status of life is to be enmeshed in other life. Our conscious minds and progressive societies seem slow to realize this, but our subconscious immune systems may have known it all along." How do you effectively communicate to a general audience the health benefits to your immune system of increasing your contact with natural diversity? How might you design a campaign to promote a certain level of "dirty" living? (Other campaigns to explore: raw milk, fermented/"live" foods)