vipers use infrared wavelengths to track prey heat signatures. Yu and Pierce quickly noticed that scientists have categorized and scrutinized the patterns humans can see on butterfly wings for centuries, but surprisingly little research had examined those patterns using light outside the visible spectrum—even though there is no reason to expect butterfly patterns evolved for human eyes.

One reason for the patterns, they reasoned, could be to aid butterflies’ reactions to radiant heat: the infrared light we can feel in sunlight. Butterflies, it seems, sense heat in much the same way, carefully moving their wings to avoid overheating. In experiments, the authors observed captive butterflies taking many different steps—leaning away, side-stepping, and turning to minimize their shadows—to absorb as little radiant heat as possible.

This effect, Pierce says, is particularly pronounced in the genus Lycaena: “If you pull up images of Lycaena on the Internet, you can see every time there’s sunshine, the butterfly is minimizing its shadow. All of a sudden you start seeing things that you didn’t see before, when you think about it in terms of temperature.”

Microscopic imagery of living butterfly wings revealed one reason why they may be so sensitive to heat. The pheromone–secret ing “scent pads” and sensory cells draw oxygen and nutrients from two sets of vessels carrying air and blood-like hemolymph to the wings. But where some insects make do with one tubular heart in their thorax, the hemolymph appears to need an extra push to suffuse large butterfly wings. The authors observed the regular beating of what they call a “wing heart”—often on the perimeter of the scent pad—pumping hemolymph through the veins on the wing.

To understand how the wings interact with infrared light, the Pierce and Yu labs used an infrared imager developed by Yu’s graduate student Cheng-Chia Tsai to “photograph” butterfly specimens from the Museum of Comparative Zoology in infrared wavelengths. This revealed dramatic, previously invisible patterns of infrared reflection in the scales covering the wings. Microscopic images of the most reflective wing scales revealed tubes thinner than a strand of hair...that shed excess heat as infrared light....

Microscopic images of the most reflective wing scales revealed tubes thinner than a strand of hair...that shed excess heat as infrared light....

red light, and thus stay far cooler than they would otherwise. These parts of the wings, says Pierce, seem to correspond with the most “alive” parts—the scent pads, veins, and wing heart—suggesting that their high reflectance, and butterflies’ heat-avoiding behaviors, are dedicated to keeping sensitive organs cool.

It’s a result that shows that living systems can prove far more complex than what can be revealed by examining dead or “fixed” tissue, said Nipam Patel, a lepidopterist at the Marine Biological Laboratory in Woods Hole who was not involved in the study. “We always thought of these structures as passive,” he said. “We come to reasonable assumptions...but when we look at living cells, we’re often surprised.”

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INFLAMMATION’S ORIGINS

Sleep, diet, exercise, and stress: these are factors known to change a person’s risk of developing numerous non-communicable diseases. Such lifestyle impacts on health—beneficial or harmful—exert much of their influence via inflammation. About 10 years ago, Matthias Nahrendorf began wondering just how inflammation and lifestyle might be linked biologically, and started thinking about how to pinpoint the mechanism in the cardinal

Matthias Nahrendorf uses equipment like this PET/CT imaging scanner to study the role of white blood cells in inflammation.
case of cardiovascular disease.

A person’s level of inflammation can easily be measured with a simple white blood cell test. White blood cells fight off bacterial invasions and repair damaged tissues, but they can also damage healthy tissue when they become too abundant. “You can find them in atherosclerotic plaques, and you can find them in acute infarcts,” says Nahrendorf, a professor of radiology who conducts high-resolution imaging research at Massachusetts General Hospital. “You can find them in failing hearts and the brain,” where they increase the risk of stroke.

When Nahrendorf learned that the most potent, toxic, and pro-inflammatory white blood cells live only a few hours, or at most a day, he immediately realized that the paramount questions—given that they die off quickly yet remain abundant in the blood—are, where and why are they produced? What is their source? Perhaps, he hypothesized, lifestyle factors regulate hematopoiesis (blood production).

To test this idea, he decided to study the effects of exercise on the production of these leukocytes in healthy mice. First, though, he consulted the scientific literature on exercise in mice. Previous researchers, he learned, had found that exercise increases production of inflammatory immune cells—which I thought was counterintuitive,” Nahrendorf recalls. When he looked more carefully, he discovered that the type of exercise used in the studies was “forced” and thus “possibly stressful” because it was induced by electric shocks. He therefore decided to test only voluntary exercise. He and his colleagues put a wheel in each mouse’s cage, so the animals could “choose to run if they were interested.”

The mice never ran during the day. “That is when they rest,” Nahrendorf explains. But in the dark, they ran a lot, averaging “six to seven miles every night.” After three weeks, the exercising mice had measurably lower levels of circulating white blood cells. Exercise, he found, had pushed their blood stem cells (cells that can produce all the different types of blood cells) into a state of quiescence: a kind of dormancy in which they generate fewer pro-inflammatory white blood cells and platelets, without decreasing the number of oxygen-carrying red blood cells. Soon the exercising mice had fewer circulating white blood cells than their sedentary counterparts, dampening inflammation—an effect that persisted for weeks.
The local signals within bone marrow that induce quiescence in blood stem cells were already well known, but the fact that exercise could trigger them was not. Nahrendorf next wanted to learn the identity of the trigger linking exercise to blood stem cell quiescence. Further investigation revealed that the only receptors with enhanced activity in the bone marrow niche where most blood stem cells exist were binding to a well-known hormone called leptin; it is produced by fat cells and regulates hunger.

Leptin is like the fuel gauge in a car. When the tank is full—meaning energy (and food) are abundant—leptin levels run high. As exercise uses up the gas in the tank, this lowers leptin levels, which signal that reserves are running low, thereby inducing hunger and the urge to eat in order to replenish depleted energy stores. Nahrendorf and his co-authors speculate in their 2019 Nature Medicine paper that leptin’s “role in regulating energetically costly hematopoiesis may have evolved to produce blood cells” only when whole body energy was abundant—not when people are exerting themselves. “Contemporary sedentary behavior,” they continue, “which increases leptin and consequently hematopoiesis, may have rendered this adaptation a risk factor for cardiovascular disease (CVD) and perhaps also for other diseases with inflammatory components.”

But with fewer circulating immune cells, would exercising mice be more vulnerable to infection? Nahrendorf challenged them with a protocol designed to induce infection in the blood, and found just the opposite: exercising mice had a more robust immune response, as semi-dormant blood stem cells swiftly sprang into activity and produced infection-fighting leukocytes, improving survival of the active mice as compared to those with no running wheels in their cages. Next, they investigated whether exercise would help mice with established atherosclerosis, and found that exercise was not only protective, it also reduced the size of existing plaques in the aorta.

Whether these associations would hold up in humans remained an open question. For answers, Nahrendorf turned to a study known as CAN-TOS, which had measured levels of inflammation in 4,892 patients who suffered heart attacks (see “Raw and Red Hot,” May-June 2019, page 46). When he approached the study’s co-authors, Mallinckrodt professor of medicine Peter Libby and Braunwald professor of medicine Paul Ridker, he learned, serendipitously, not only that they possessed self-reported exercise levels for the participants, but also that they had tested leptin levels as well. They analyzed their raw data and found “the same relationship among exercise, leptin, and leukocytes as in the mice.” Data from a second human study cemented the result.

By identifying a previously unknown molecular mechanism linking voluntary exercise to reduced white blood cell production, Nahrendorf and his colleagues have highlighted how a lifestyle factor can modulate cardiovascular risk. Their discovery, the researchers hope, will point the way to wider adoption of healthy exercise regimens, and health-enhancing anti-inflammatory drugs.

By linking exercise to reduced white blood cell production, Nahrendorf shows how a lifestyle factor can modulate cardiovascular risk.

The Risks of Homeschooling

A rapidly increasing number of American families are opting out of sending their children to school, choosing instead to educate them at home. Homeschooled kids now account for roughly 3 percent to 4 percent of school-age children in the United States, a number equivalent to those attending charter schools, and larger than the number currently in parochial schools.

Yet Elizabeth Bartholet, Wasserstein public interest professor of law and faculty director of the Law School’s Child Advocacy Program, sees risks for children—and society—in homeschooling, and recommends a presumptive ban on the practice. Homeschooling, she says, not only violates children’s right to a “meaningful education” and their right to