



Forest bathing in Shinanomachi, Japan, a practice in which participants spend time in nature to benefit their health.

Into the woods

Forests release organic compounds that seem to improve lung health, but the magnitude and mechanism of the effect are unclear. **By Erica Gies**

During the COVID-19 pandemic, Italian scientists documented something interesting: in areas with more trees per capita, the number and severity of COVID-19 cases were lower than in places with fewer trees, even when accounting for differences in human population density¹. This work is part of a growing body of research around the world investigating whether time spent in forests and nature can provide protection from infections, such as COVID-19 and pneumonia; inflammatory

conditions, such as asthma, emphysema and bronchitis; and even cancer.

'Touch grass' has become the rejoinder to stop using electronic devices and to go outside. It's part of a long-held belief that nature is good for us. The ancient Celts prescribed time sitting next to certain plants as medicine for particular ailments, says conservationist Melinda Gilhen-Baker at the Canadian Parks and Wilderness Society in Ottawa. In Japan, forest bathing (*shinrin-yoku*) is the traditional practice of spending time in the

woods for one's health.

That culture spurred a Tokyo-based research team to establish the field of forest medicine. Now Japan has adopted it as a national health strategy, with therapy bases in forests across the country. South Korea also operates at least 76 'healing forests', and integrates forest therapy – guided slow walking, deep breathing or meditation in forests – into its National Health Insurance Service. Physicians in other countries, including the United States and the United Kingdom, are



Water spray, such as from Indonesia's Nungnung Waterfall, might contain healthy microbes.

also prescribing forest time.

Forests and nature are widely known to buffer humans from respiratory conditions, such as asthma, that are exacerbated by air pollution from cars and industry. Forests are mostly free of these pollution sources, and particles that drift in from urban areas are intercepted by leaves. Forests are also cooler than cities, thanks to the water vapour that plants release during photosynthesis. Higher urban temperatures combined with pollution can form smog, which causes respiratory distress.

Expanses of wilder nature – areas largely inaccessible to people – also shield humans from diseases carried by other animals. Human activities, including the felling of one-third of the world's forests, have degraded more than 75% of land on Earth, threatening its ability to sustain the lives of plants and animals, including humans. As people push into areas where wild animals live, they can come into contact with new diseases, says Gilhen-Baker. Outbreaks of diseases, such as COVID-19, are becoming more common, and some scientists suggest that forest restoration could provide protection.

Assessing the benefits

A key question is whether forest bathing improves health, rather than just offering people a break from urban sources of harm.

Many urbanites say that hiking and camping in nature leaves them feeling calmer and

less stressed. Although that feeling could simply be down to doing something fun instead of working, there is another explanation: people evolved in nature. Research suggests that submersing the senses in fluttering leaves, dappled light, chirping birds or a burbling brook calms the autonomic nervous system, boosting mood and immune function.

That calming effect is not purely subjective. Immunologist Qing Li leads the forest research laboratory at the Nippon Medical School in Tokyo and has been conducting field experiments for 30 years. Li and other researchers have measured decreases in stress hormones such as cortisol and adrenaline, pulse rate and blood pressure after people spend time in nature. Almost all studies in this realm attempt to separate out possible benefits from, say, exercise, leisure or other factors unrelated to being in nature.

Those physical responses can boost mood and heart health, but also have broader benefits for the body, says Li, who is vice-president of the International Society of Nature and Forest Medicine. We should think of the human body not as a collection of separate systems, he says, but like the forest itself – a complex ecosystem with interlinking reactions. Through his research², he has detected changes to the nervous, immune and inflammatory systems after people spend time in the forest, and he contends that measurable impacts on one system affect the

performance of the others. But nature also offers actual medicine, according to researchers, such as Li.

Forests smell good: like pine, lemon or herbs. Those aromas come from phytoncides – biochemical compounds that plants' immune systems emit to protect themselves from insects, bacteria, protozoa and fungi. And the human immune system has been shown to react positively to them.

Active ingredients

The main components of phytoncides are terpenes, which make up the majority of biogenic volatile organic compounds (BVOCs). "These substances can counteract plant parasites, but they are also beneficial for mammals," says Michele Antonelli, who practices preventive and integrative medicine in Reggio Emilia, Italy.

Anyone who spends time in the forest inhales these BVOCs, which can be detected in the blood. Studies have shown that some terpenes have antibacterial, antifungal and antiviral properties, and Antonelli thinks this suggests that "inhalation of certain terpenes may directly help combat infections, particularly in the airways".

The largest producers of terpenes and other BVOCs are conifers, such as pines, cedars and spruce. The concentration of the compounds in the air increases with temperature, suggesting that midday forest bathing might maximize a person's exposure. Terpene concentration peaks in spring, but one small study³ found that even during winter, when terpene levels



The bacterium *Streptomyces coelicoflavus*.

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ebb, forest bathing reduced blood pressure and bolstered the immune system.

It's not just the trees that provide benefits: the soil microorganism *Mycobacterium vaccae*, for example, seems to boost immune functioning⁴. And a soil-dwelling bacterial genus called *Streptomyces* is used in many antibiotics.

Environmental features commonly found in and around forests, such as waterfalls and fast-moving rivers, can also be good for health. The aerosolized water that they spray might contain beneficial microbes, and charged ions in the air that surrounds moving water might aid the immune system, especially in the respiratory tract⁵. Antonelli says that the aerosolized water can also increase a person's exposure to the terpenes released by trees.

Phytoncides inhaled in the forest seem to improve immunity by increasing the activity and number of white blood cells called natural killer cells, Li says. The phytoncides also increase anticancer proteins in these cells. Natural killer cells attack tumour- and virus-infected cells in the body, and these changes could protect against such threats, he says.

Inhaling phytoncides has been shown to decrease inflammatory molecules called cytokines⁷, which play a key part in inflammatory lung diseases, such as asthma and chronic obstructive pulmonary disease (COPD).

State of the science

Although various meta-analyses find that exposure to nature is beneficial, some researchers have raised concerns about study design.

Conservationist and statistician Peter Kareiva has called for better research into the benefits of exposure to nature, especially in cities⁸. He doesn't doubt that nature experiences lead to real health benefits, but cautions that some of the papers' findings are "just correlative". People who live next to parks might also exercise more or have a better diet, says Kareiva, who is now retired and was the director of the University of California, Los Angeles's Institute of the Environment and Sustainability.

That correlation could point to an alternative explanation for the beneficial results of a study that measured neighbourhoods using a 'greenness' index. People living in neighbourhoods with more vegetation were significantly less likely to develop asthma or lung cancer, and less likely to die of COPD than those living in less green neighbourhoods⁹. That's why, Kareiva says "it's really important that you have randomized trials, because otherwise you could just be selecting people with a lifestyle, a diet choice, and all sorts of things that go along with forest bathing that contribute just as much as forest bathing".



Wooded areas around Beijing.

Some studies on forest bathing also include an "incredibly small" number of participants, says Kareiva. Moreover, he says, studies that do document physiological changes typically don't follow up on them later. Researchers can't, therefore, say whether the changes last long enough to have a significant effect on people's health.

"Inhalation of certain terpenes may directly help combat infections."

Antonelli acknowledges these shortcomings in forest-medicine research, but says that some are inevitable, owing to the complexity of a natural-forest environment. "It's quite hard to design a perfect study because there are very many confounding factors," he says. For example, it's difficult to measure the precise quantity of BVOCs that a person inhales outside. Some studies are performed indoors, where researchers can pipe in a set quantity of a particular terpenes, to control variables. But that approach strips out key elements of the forest-bathing experience, such as sight and sound, or any benefits that could come from inhaling multiple compounds together, say researchers. In regard to the need for follow-up

studies, Li points to his own research. He says that his studies show beneficial changes in the body that last for up to a month.

Both Li and Antonelli stress that, so far, research into forest medicine only documents the possibility of it protecting existing health, rather than curing specific diseases. Researchers have not yet undertaken studies to determine this – a gap that Antonelli attributes to poor funding for the field. "While we can't claim direct causation between forest medicine and disease outcomes," he says, "we can point to the biological mechanisms and their known links to health." For example, research has shown that the number and activity of natural killer cells increases after forest bathing, and that those changes protect against cancer¹⁰. Similarly, phytoncides have been shown to decrease cytokines, and separate studies show that cytokines play a key part in asthma and COPD^{6,7}.

Still, Kareiva cautions that forest bathing might not be the optimal investment for public health. Even if researchers measure statistically significant health benefits from it, he says, it's important to evaluate how it stacks up against preventative and therapeutic alternatives. "If you're worried about lung health" he says, "the best thing to do might be to clean up pollution."

Of course, minimizing pollution and ensuring space for forest bathing might point to the same solution: restoring forests. Globally, the destruction of nature, such as deforestation, continues. Industrial agriculture and logging dry out land and make it more flammable – contributing, along with climate change, to the rise in extreme forests fires. The smoke wafting across continents has led to well-documented lung problems. Rehydrating the land by restoring ecosystems is therefore a 'two for one' solution in terms of human health: land is less likely to burn and cause lung illnesses, and more likely to support vegetation that could offer forest-medicine benefits.

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1. Roviello, V. & Roviello, G. N. *Environ. Chem. Lett.* **20**, 7–17 (2022).
2. Li, Q. *Forests* **14**, 1024 (2023).
3. Peterfalvi, A. et al. *Int. J. Environ. Res. Public Health* **18**, 2067 (2021).
4. Holbrook, E. M. et al. *Int. J. Mol. Sci.* **24**, 5176 (2023).
5. Andersen, L. et al. *Int. J. Environ. Res. Public Health* **18**, 1416 (2021).
6. Li, Q. et al. *Int. J. Immunopathol. Pharmacol.* **22**, 951–959 (2009).
7. Jia, B. B. et al. *Biomed. Environ. Sci.* **29**, 212–218 (2016).
8. Marvier, M., Kareiva, P., Felix, D., Ferrante, B. J. & Billington, M. B. *Proc. Natl Acad. Sci. USA* **120**, e2304126120 (2023).
9. Tang, M., Liu, W., Li, H. & Li, F. *Front. Public Health* **11**, 1279322 (2023).
10. Coënon, L. et al. *Cell Death Dis.* **15**, 614 (2024).