2. The MICrONS Consortium *et al*. *Nature* **640**, 435–447 (2025).
3. Douglas, R. J., Martin, K. A. C. & Whitteridge, D. *Neural Comput.* **1**, 480–488 (1989).
4. Motta, A. *et al*. *Science* **366**, eaay3134 (2019).
5. White, J. G., Southgate, E., Thomson, J. N. & Brenner, S. *Phil. Trans. R. Soc. Lond. B* **314**, 1–340 (1986).
6. Winding, M. *et al*. *Science* **379**, eadd9330 (2023).
7. Scheffer, L. K. *et al*. *eLife* **9**, e57443 (2020).
8. Dorkenwald, S. *et al*. *Nature* **634**, 124–138 (2024).
9. Loomba, S. *et al*. *Science* **377**, eabo0924 (2022).
10. Shapson-Coe, A. *et al*. *Science* **384**, eadk4858 (2024).
11. Celii, B. *et al*. *Nature* **640**, 487–496 (2025).
12. Dorkenwald, S. *et al*. Preprint at bioRxiv https://doi.org/10.1101/2023.07.26.550598 (2023).
13. Schneider-Mizell, C. M. *et al*. *Nature* **640**, 448–457 (2025).
14. Elabbady, L. *et al*. *Nature* **640**, 478–486 (2025).
15. Gamlin, C. R. *et al*. *Nature* **640**, 497–505 (2025).
16. Ding, Z. *et al*. *Nature* **640**, 459–469 (2025).
17. Wang, E. Y. *et al*. *Nature* **640**, 470–477 (2025).
18. Sievers, M. *et al*. Preprint at bioRxiv https://doi.org/10.1101/2024.03.22.586254 (2024).

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Medical technology

Wound healing measured by molecular flux

Kellen Chen and Geoffrey C. Gurtner

A non-contact wearable device measures the skin's 'microclimate' for continuous, real-time monitoring of wounds and wound healing. **See p.375**

The skin is the largest organ of the human body, maintaining internal homeostasis – for example by releasing heat through sweating on a hot day – and providing a barrier that protects the body from external threats such as bacteria and other microorganisms. But skin is also highly vulnerable to injury. Chronic, non-healing wounds can increase the susceptibility of the body to infection, increase the complications of elective surgical procedures and greatly add to health-care costs[1]. On page 375, Shin *et al*.[2] present details of a non-contact wearable device that can continuously monitor wounds and wound healing by measuring the flux of molecules into and out of the skin, potentially decreasing treatment costs and improving patient outcomes.

Wearable technologies are seen as having great potential to fill gaps in an often fragmented and disjointed health-care systems. In most modern systems, if a person is ill enough, they will be admitted to a hospital to enable their condition to be monitored continuously, with complex technologies used to diagnose and treat them. But because this is expensive and resource-intensive, there is a great incentive for people to be discharged quickly to reduce the immediate costs of care. Often, this actually increases costs overall: with less frequent monitoring, perhaps weekly or monthly, in a doctor's office or clinic, patients' health can deteriorate, leading to complications and sometimes even re-admission to hospital[3].

Wearables – complemented and powered by advances in sensors, robotics and computer vision – are beginning to make possible an alternative approach, in which people with long-term, complex conditions are monitored by technology and autonomously treated without direct involvement of a physician. The skin is an attractive test bed for this approach. Chronic, non-healing wounds – including diabetic foot ulcers, venous leg ulcers and pressure sores – prevent the skin from functioning normally and often lead to disability[4]. These affect more than eight million individuals in the United States alone each year[5,6], costing Medicare, the government insurance scheme for older people and those with disabilities, something between US$28 billion and $97 billion annually[6]. Currently, trained professionals diagnose wound infection in the clinic on the basis of cardinal symptoms of increased pain, redness, swelling and warmth.

Shin *et al*.[2] present a wearable device that creates an enclosed chamber over an area of skin and uses integrated wireless sensors to measure the skin's 'microclimate'. It can robustly detect streams of vaporized molecular substances, including water vapour, carbon dioxide and volatile organic compounds passing into or out of the skin's surface (Fig. 1). This skin flux has long been known to occur, but has proved difficult to measure in a rigorous, controlled and continuous way.

The authors show in studies on human volunteers that their device can detect increased water flux during perspiration. It can also sense increased organic-compound flux when an individual has a build-up of bacteria on their skin, for example when they have not showered or otherwise cleaned themselves. In preclinical animal models, the authors observed a strong correlation between the presence of open wounds and an increased flux of water vapour. They also found that the presence of diabetes, a known risk factor for impaired wound healing, dramatically increased the time needed to re-establish wound-barrier function, as measured by water flux. These findings correlate well with ongoing work measuring water flux in humans with bulky, handheld trans-epidermal water-loss devices[7]. Infected wounds could also be detected through increased organic-compound flux using Shin and co-workers' device.

Such a device could enable remote and continuous wound monitoring when patients are at home, in contrast to conventional methods to monitor skin wounds that require a trained professional to make a reading using

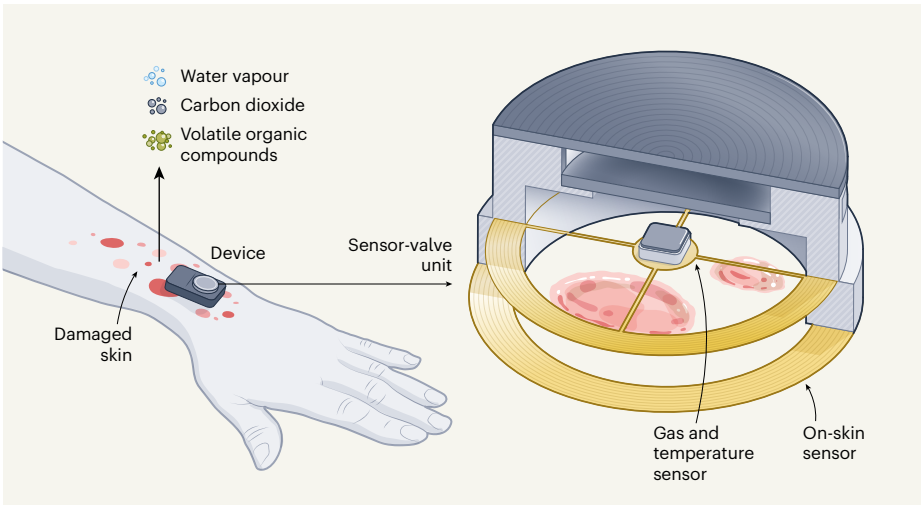

Figure 1 | A non-contact device for real-time monitoring of skin wounds. Skin wounds and unclean skin can produce an elevated flux of water vapour, carbon dioxide and volatile organic compounds (VOCs) in the immediate vicinity of the skin. A wearable device[2] uses wireless gas and temperature sensors, as well as on-skin sensors for temperature, impedance (a measure similar to electrical resistance) and thermal conductivity, to enable remote monitoring of skin health in people with long-term conditions.

a handheld device. But although promising, certain aspects of this technology need more work. The practicalities of wearing such a device for long periods of time must be explored: factors such as comfort, pain, irritation and how strongly the chamber adheres to the skin remain unanswered questions. It also seems probable that this device in its current iteration would be too bulky to monitor certain common types of wound, such as diabetic foot ulcers, which generally occur on the bottom of the foot.

Equally, it remains to be seen whether the technology can be scaled for large-area surface wounds such as a venous leg ulcers, which can span the entire circumference of the lower leg. Larger clinical trials will also be needed involving people with various physiques, ages and skin tones, because differences in skin properties could affect the reliability of measurements (for example, older skin is mechanically weaker and less elastic than younger skin).

Alternative designs for prototype 'smart' devices have also shown promise in their ability to sense physiological conditions using different sensors and monitors[8]. In contrast to molecular markers, biophysical signals such as temperature, impedance (a measure similar to electrical resistance) or pH might provide rapid, robust and accurate information using simpler technology[8,9]. But regardless of the precise approach, continuous, non-invasive, and wireless monitoring of skin and wounds will enable an earlier diagnosis of non-healing or infection to enable timely initiation of treatment. Any technology that can identify and treat infection early and promptly has the potential to revolutionize wound care and significantly improve outcomes for patients.

Kellen Chen and **Geoffrey C. Gurtner** are in the Department of Surgery, University of Arizona, Tucson, Arizona 85724, USA.
e-mail: gurtner@surgery.arizona.edu

1. Sen, C. K. *Adv. Wound Care* **10**, 281–292 (2021).
2. Shin, J. *et al. Nature* **640**, 375–383 (2025).
3. Hicks, C. W. *et al. J. Vasc. Surg.* **70**, 1263–1270 (2019).
4. Werdin, F., Tenenhaus, M. & Rennekampff, H.-O. *Lancet* **372**, 1860–1862 (2008).
5. Han, G. & Ceilley, R. *Adv. Ther.* **34**, 599–610 (2017).
6. Nussbaum, S. R. *et al. Value Health* **21**, 27–32 (2018).
7. Hajhosseini, B., Gurtner, G. C. & Sen, C. K. *Plast. Reconstr. Surg. Glob. Open* **7** (4S), 34–35, abstr. 48 (2019).
8. Jiang, Y. *et al. Nature Biotech.* **41**, 652–662 (2023).
9. Li, S., Renick, P., Senkowsky, J., Nair, A. & Tang, L. *Adv. Wound Care* **10**, 317–327 (2021).

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Cancer genetics

Mutations that set the stage for stomach cancer

Callum Oddy & Marnix Jansen

Comprehensive maps of mutations in healthy and diseased gastric tissue give clues about how cancer arises and could inform early-detection strategies. **See p.418**

For decades, scientists have understood the importance of mutations in cancer development, also known as carcinogenesis. What has been less clear is the part played by mutations in normal tissues in setting the stage for cancer to evolve. As we age, we accrue mutations: they can appear as a result of insults (for example, by-products of normal metabolism that can damage DNA) or through errors in DNA replication as part of the normal cell cycle. These mutations can bring about changes to normal cells. And by understanding how and why mutations arise, powerful insights into processes such as carcinogenesis and ageing can be derived. On page 418, Coorens *et al.*[1] report an analysis of human stomach tissues that charts the mutational landscape across normal, precancerous and cancerous stages.

In the inner surface layer (epithelium) of the stomach, gastric glands produce mucus to protect the stomach lining, hydrochloric acid for digestion and digestive enzymes such as pepsinogen. But this environment is harsh, with a low pH, frequent abrasion and constant exposure to pathogens[2]. To maintain a healthy gastric epithelium, stem cells in glands give rise to new cells, which migrate upwards to replenish the surface lining[3]. This high rate of cell turnover increases the risk of incurring mutations.

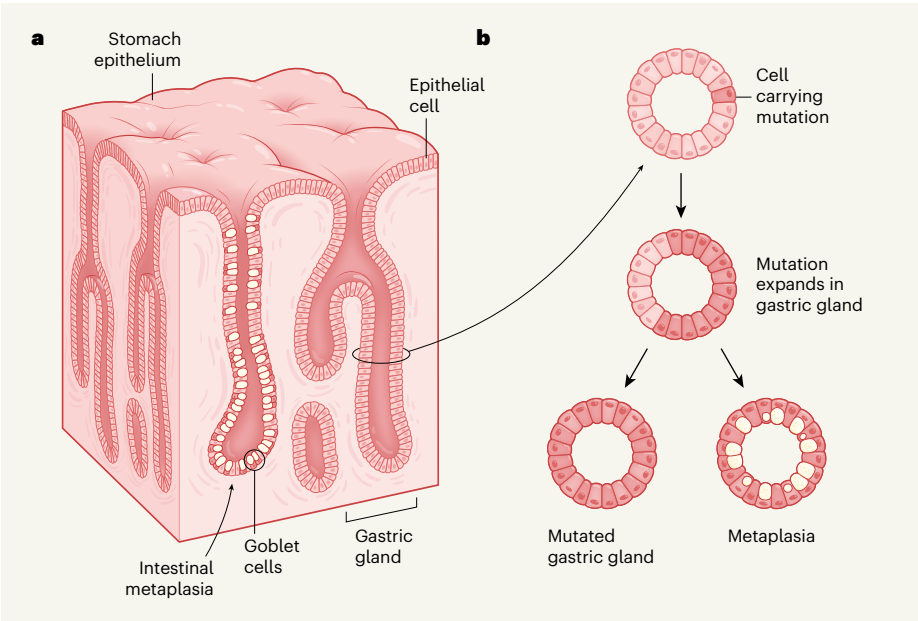

Figure 1 | Mutations in stomach epithelium. a, Coorens *et al.*[1] examined how mutations that are acquired through life might prime the stomach for cancer development. The authors carried out whole-genome sequencing on structures called gastric glands, which produce mucus, hydrochloric acid and digestive enzymes in the stomach's inner surface (epithelium). Prolonged exposure to damaging conditions, in particular chronic infection with the bacterium *Helicobacter pylori*, can provoke a tissue transformation, called intestinal metaplasia, which is a precursor to gastric cancer. Metaplastic glands contain goblet cells, specialized epithelial cells that are normally found in intestinal tissue. **b**, With age, cells incur mutations that can expand in a gland through normal cell division. Glands that undergo metaplasia carry many more mutations than do normal glands, and the authors suggest that this transformation is a key event in setting the stage for tumour formation.