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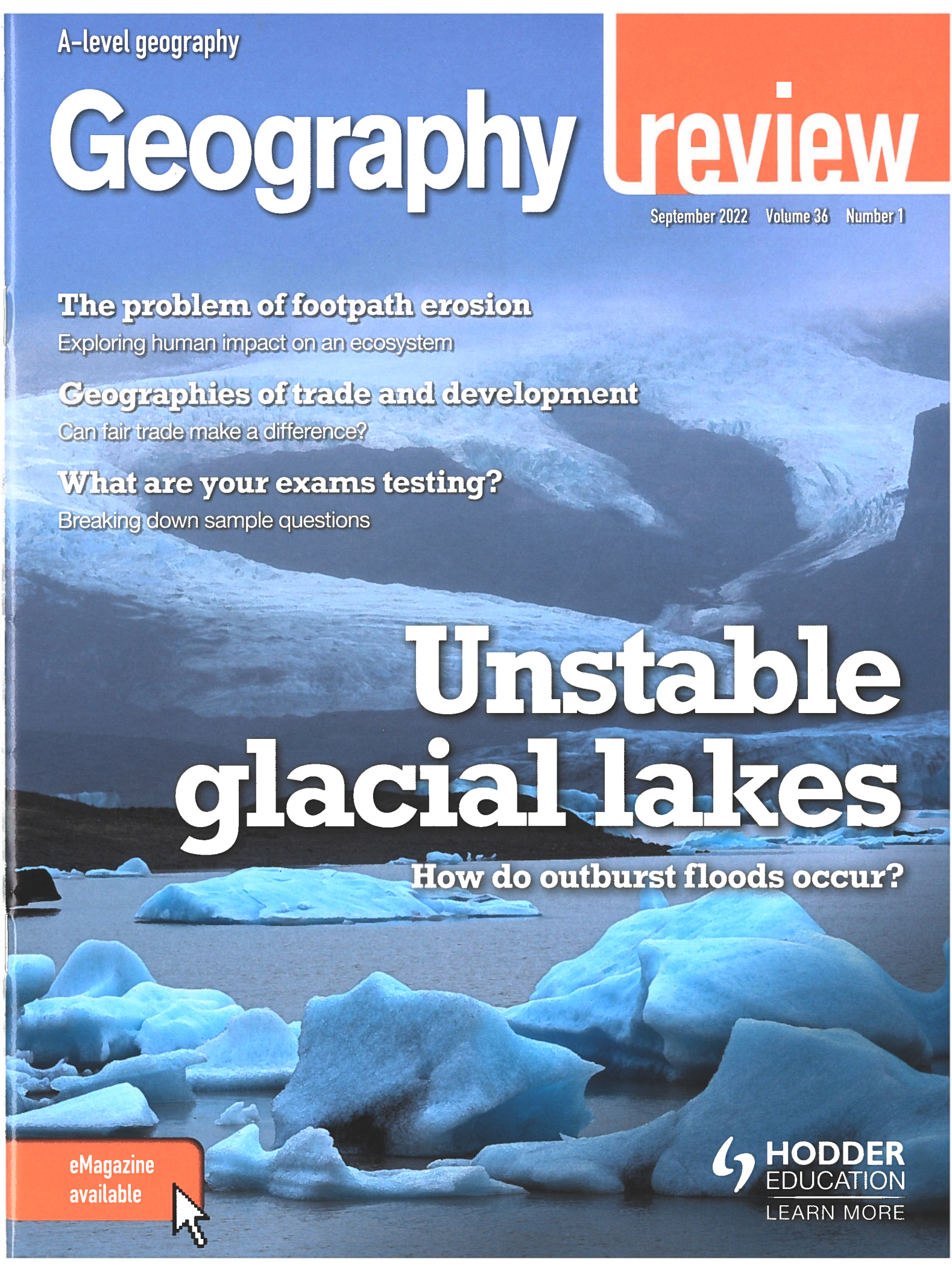

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Tracking the spread of Covid-19

Matthew Smallman-Raynor and Sarah Jewitt

This article tracks the early stages of the global diffusion of the Covid-19 pandemic, and assesses its rate of spread through the Worldwide Air Transportation Network (WAN)

EXAM LINKS

- OCR: Disease dilemmas
- AQA: Population and the environment

Communicable diseases are capitalising on our highly connected world to spread as global **pandemics**. Covid-19 is the most recent example, but new and potentially lethal **communicable diseases** are appearing in the human population with alarming regularity. Ebola virus disease, 'bird flu' (avian influenza A/H5N1) and the Middle East respiratory syndrome (MERS) are prominent examples that have made the headlines in recent times. Swift action by national and international health agencies has ensured that many of these emerging diseases have been contained at the local or regional levels. Some, however, have evaded containment efforts and have spread around the world.

Box 1 Changing rates of pandemic transmission

Figure 1 shows the time in months that it took successive pandemics of one viral disease (influenza) to diffuse across Europe, 1701–2020. In the 1700s, an influenza pandemic took some 8–12 months to spread across the continent. By the mid-1850s, the time had been cut to 6 months and, by the twentieth and early twenty-first centuries, it had fallen to 3–4 months. These developments were the product of advances in transportation technology that brought distant parts of the continent ever closer in terms of travel time.

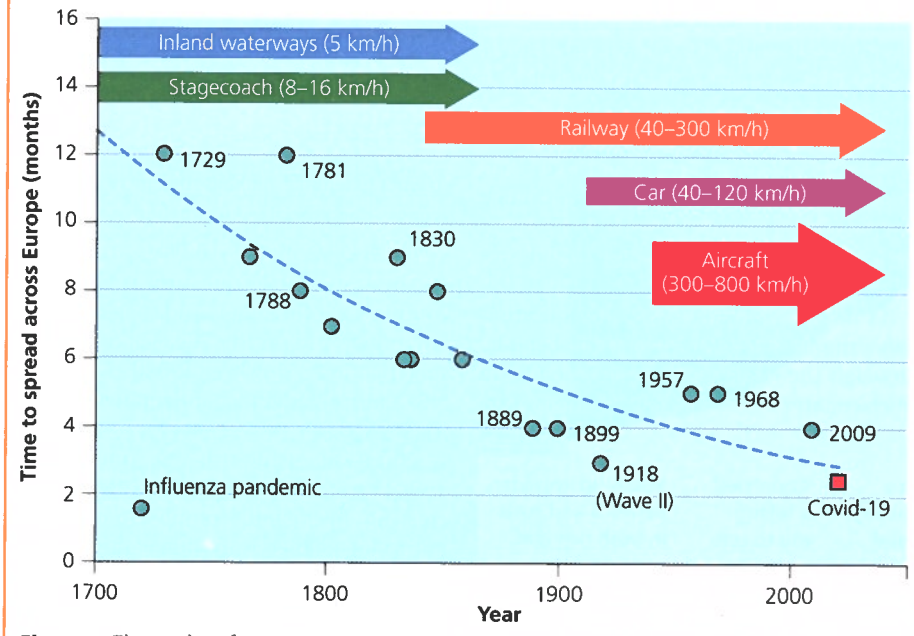


Figure 1 Time taken for successive pandemics of influenza to diffuse across Europe, 1700–2020

Time–space compression

The global transportation network is fundamental to understanding the pace at which communicable diseases can spread from country to country. As the network has evolved to include faster and more efficient modes of transportation, so once distant parts of the world have moved ever closer together in time. One outcome of this development (which geographers refer to as **time–space compression**) has been an acceleration in the pace at which pandemics have diffused across continents (see Box 1 and Figure 1).

Ground zero of a pandemic

On 31 December 2019, the **World Health Organization** (WHO) was alerted to an unusual cluster of 41 pneumonia patients in the massive urban sprawl of Wuhan City, the capital of China's Hubei province. The patients displayed breathing difficulties and fever. Some developed severe respiratory distress

GLOSSARY

Communicable disease A disease caused by microorganisms (for example, viruses, bacteria and protozoa) that can be transmitted directly or indirectly from one host to another.

Pandemic A term used in the scientific literature to describe an infectious disease that is geographically widespread.

Time–space compression A contraction in the relative separation of places as a result of technological advances.

World Health Organization (WHO) The agency of the United Nations (UN) responsible for international public health.

and organ dysfunction, and several died in intensive care. Examination of the patients revealed evidence of a previously unknown virus that was distantly related to the cause of the international outbreak of severe acute respiratory syndrome (SARS) in 2002–3. The similarities were sufficient for the new virus to be named 'severe acute respiratory syndrome coronavirus 2' (SARS-CoV-2) and the associated disease 'coronavirus disease 2019' (Covid-19).

Origins

Where did SARS-CoV-2 come from to spark the Wuhan outbreak? While scientists are still trying to unravel the mystery, a WHO-sponsored investigation into the matter has provided some clues. The report noted that the virus is genetically related to a group of viruses that are carried by bats and scaly anteaters (pangolins). These creatures may be possible sources of SARS-CoV-2 in nature and the virus may have 'spilled over' to humans at some point in the recent past (see Box 2).

Because many of the earliest recognised human cases in Wuhan were linked to the city's Huanan seafood market, where live animals (including bats, frogs, snakes, birds, marmots and rabbits) were offered for sale, there has been speculation — although no conclusive evidence — that the virus originated there. The same report deemed it extremely unlikely that SARS-CoV-2 had escaped from a Wuhan research laboratory. Investigations are ongoing.

Early diffusion

Wuhan was locked down on 23 January 2020. But it was too late to contain the spread of the disease. Covid-19 was already moving rapidly along China's high-speed rail (HSR) and domestic airline networks to other parts of the country — a spread process that was accelerated by the mass population movements that accompanied the Chinese New Year holiday. Cases of Covid-19 also began to appear in other countries of Asia, and then Europe and the Americas. The overwhelming majority of these early international cases were linked to Wuhan (Figure 2).

Figure 2 The international spread of Covid-19 from China

Wuhan, where the virus now known as Covid-19 was first detected in late 2019, is the capital of China's Hubei province

Box 2 Zoonoses, spillover events and disease emergence

Many apparently new communicable diseases in the human population originate as 'zoonoses', or infections that cross the species from animals to humans. Environmental and other changes that bring animals and humans into increased contact, and which promote the opportunities for microbial agents to cross the species ('spillover') to humans, are important factors in the disease emergence process. Examples of spillovers include Nipah virus disease (from bats), Hantavirus pulmonary syndrome (from rodents) and bird flu (from wild waterfowl and poultry).

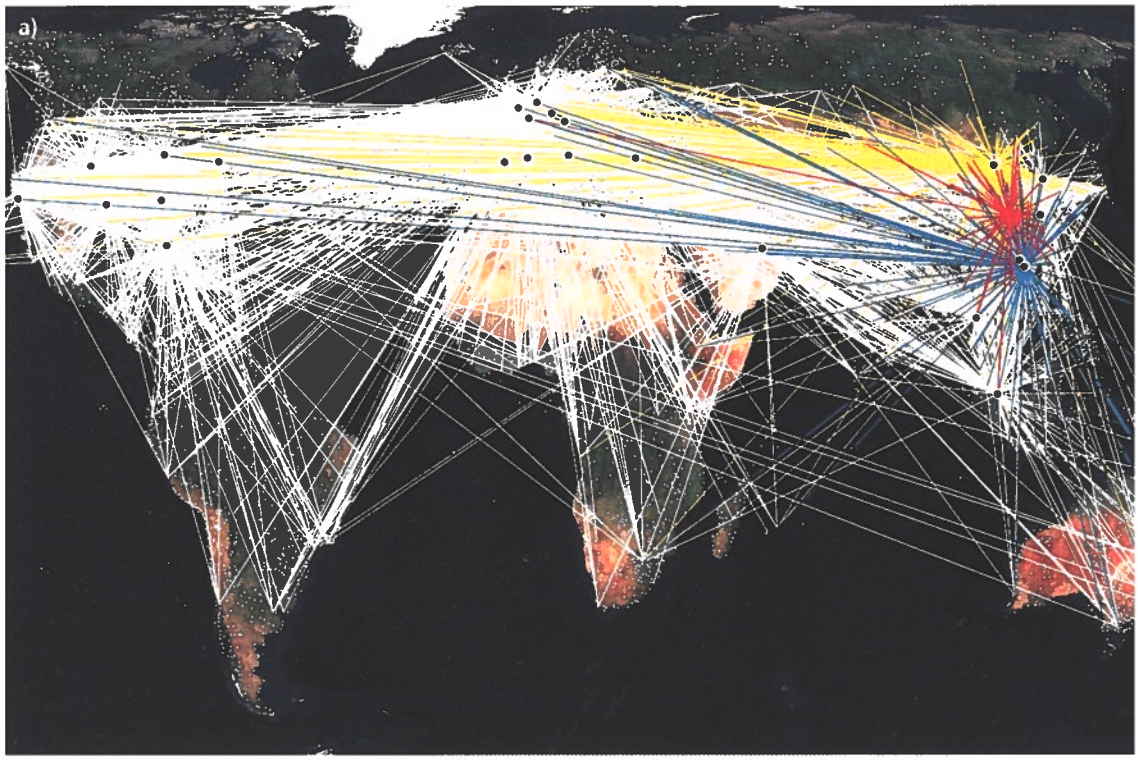


Figure 3 Global diffusion of Covid-19 (A) A section of the WAN, showing the routes of flights from 25 of the world's busiest commercial airports. Flight routes from Wuhan Tianhe International Airport are superimposed in red (B) Estimated dates of introduction of Covid-19 into each country of the world

Such were the developments that the WHO officially declared the Covid-19 situation to be a public health emergency of international concern on 30 January 2020 (see Box 3). Then, on 11 March, the WHO director-general declared a pandemic on account of 'alarming levels of spread and severity, and...alarming levels of inaction'. By this time, the disease had been documented in 114 countries, territories and areas, and the associated case count had exceeded 118,000.

The Worldwide Air Transportation Network (WAN)

Few frameworks provide a more powerful impression of present-day levels of global interaction than the Worldwide Air Transportation Network or WAN. The WAN consists of over 3,400 commercial airports, connected by some 50,000 flight routes that carry an average of 12.3 million passengers every day. Figure 4A illustrates just one small part of the WAN, namely flight routes originating from 25 of the world's busiest commercial airports. The dense network of interregional and intercontinental flight routes is striking, bringing every major city within 24 hours of each other.

The role of the WAN in the international diffusion of communicable diseases was evidenced by the SARS outbreak in 2002–3 and by the influenza pandemic in 2009–10. The same is true for Covid-19. Centred on the originating point of the pandemic, the immediate geographical reach of Wuhan Tianhe International Airport (shown as the red flight routes in Figure 3A) is largely restricted to other cities in Southeast Asia. But Wuhan is highly connected to many global flight hubs (for example, Beijing and Hong Kong) and these provided a ready opportunity for the rapid intercontinental transmission of Covid-19 in the early stages of the pandemic.

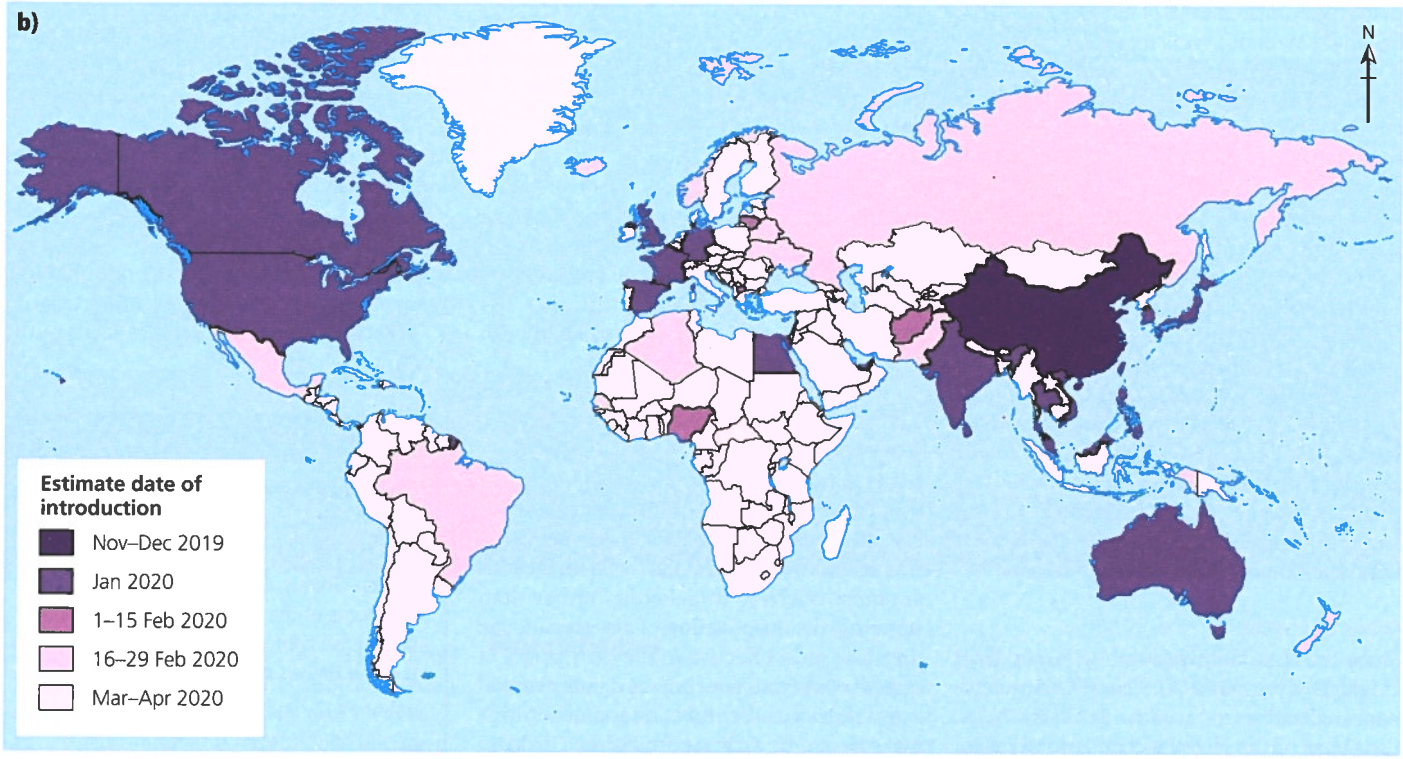
Rate of pandemic transmission

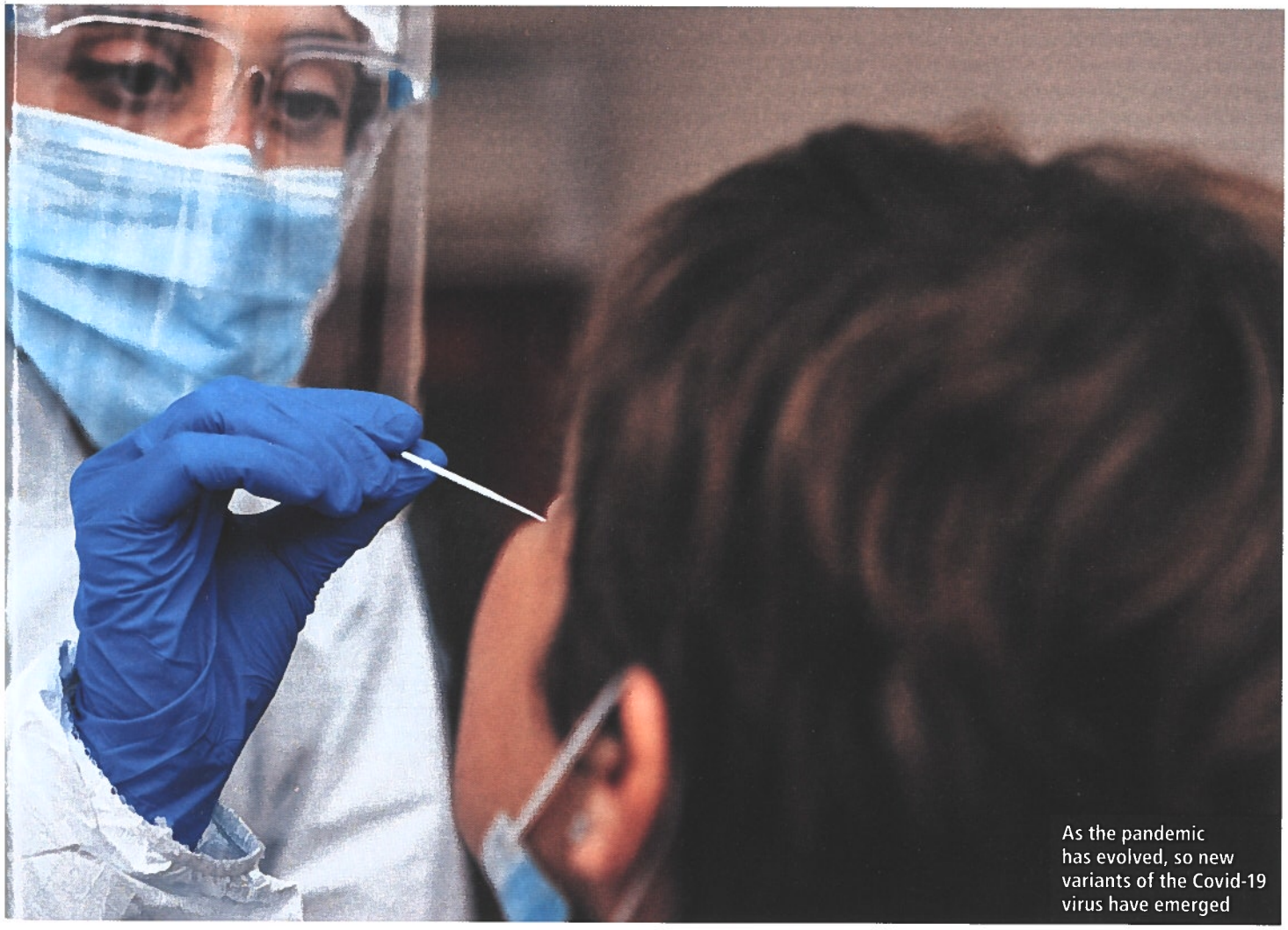
How fast did the Covid-19 pandemic spread through the WAN? Figure 3B is based on a study led by researchers at the University of Kent and

Box 3 WHO and the International Health Regulations (IHR)

The international response to Covid-19 has been guided by the International Health Regulations (IHR), the WHO's regulatory framework for the prevention of the international spread of diseases. The regulations require member states to notify the WHO of all disease events that represent a potential threat to the international community, whether naturally occurring, intentionally created or unintentionally caused. It is these regulations that informed the WHO's declaration of a public health emergency of international concern on 30 January 2020 — a declaration that sought to galvanise a coordinated international response to Covid-19.

b)





As the pandemic has evolved, so new variants of the Covid-19 virus have emerged

maps the estimated dates of introduction of the original ('Wuhan') virus into each country of the world. When these dates are indexed to the estimated date of the first case of Covid-19 in China (17 November 2019), Table 1 shows that it took an average of 106 days (~3.5 months) for Covid-19 to reach any country of the world.

The countries of the Western Pacific (83 days) and Southeast Asia (96 days), closest to the point of onset of the pandemic, were infected earliest on average. These regions were followed by the Eastern Mediterranean (101 days), Europe (102 days), Americas (111 days) and Africa (116 days). This broad geographical sequence corresponds with the increasingly lighter shading categories in Figure 3B. That the last country was reached after 146 days indicates that the Covid-19 pandemic had spread to even the most peripheral countries in the WAN within 5 months of the world's first case.

New variants

Since the first identification of the original Covid-19 virus in late 2019, new variants have appeared and spread worldwide via the WAN. Estimates of the global transmission rates of two of these variants (Alpha and Delta) are given in Table 1. The evidence indicates that the Alpha variant diffused at a similar rate to the original Wuhan virus, taking an average of 115 days (~4.0 months) to reach any country of the world. The Delta variant was somewhat slower, taking an estimated 195 days (~6.5 months).

It is important to recognise that the estimates in Table 1 are dependent on a broad range of factors. These include the quality of the available data, the ability and capacity of countries to detect the variants in a timely manner, the specific characteristics (including the transmissibility) of each variant, and the point on the Earth's surface at which each first emerged. The Delta variant, for example, appears to have been circulating in India as early as October 2020, several months prior to beginning its widespread global dissemination in the late winter and spring of 2021. When indexed to an October 2020 start date, a lengthy period of local circulation in India would account for the seemingly slow rate of global diffusion in Table 1. However, if the start date is reset to February 2021, towards the apparent beginning of Delta's international transmission, the estimated rate of global diffusion is 104 days (~3.5 months) — a similar rate to both Alpha and the original Wuhan strain.

Travel restrictions and pandemic control

Disease modellers have used the WAN to simulate the effects of air travel restrictions as a means of pandemic control. In general, these simulations have shown that travel restrictions are most effective in delaying, rather than stopping, the introduction of diseases and are therefore most effective in the early stages of spread. Many countries imposed international travel restrictions, entry bans and quarantine measures in the early months of the Covid-19 pandemic. The net effect was to greatly reduce the operations of the WAN, if not to entirely shut it down. But restrictions on travel came too late to limit the early spread from Wuhan, and many restrictions only came into force after the establishment of community transmission in multiple countries and world regions. As such, they failed to effectively limit the global spread of the pandemic.

Conclusion

In the space of a few months, Covid-19 diffused around the world to become deeply embedded in the global population. As the pandemic has evolved, so new variants of the Covid-19 virus have emerged. Some of these variants have enhanced transmissibility and some, such as the Alpha, Delta and Omicron variants, have spread as additional pandemic waves as international travel restrictions have been eased over time. Vigilance and timely action are required to avert further waves of infection as the pandemic evolves.

Questions for discussion

1 Why is the timeliness of the response to a new communicable disease so important?
2 What characteristics of Covid-19 favoured its rapid global spread?

Table 1 Global diffusion rate of Covid-19

Geographical region	Countries (n)	Average time for variant to first reach a country (days)[1]		
		Original ('Wuhan') virus (2019–20)	Alpha variant (Sept. 2020–21)	Delta variant (Oct. 2020–21)
Western Pacific	17	83	99	193 [74]
Southeast Asia	8	96	132	143 [52]
Eastern Mediterranean	21	101	129	206 [95]
Europe	58	102	93	187 [88]
Americas	44	111	131	212 [122]
Africa	47	116	131	199 [130]
World	195	106	115	195 [104]

[1] Estimates based on start dates of 17 November 2019 (original virus), 20 September 2020 (Alpha) and 28 October 2020 (Delta). The alternative estimates for Delta [in square brackets] are based on a start date of 21 February 2021, towards the apparent beginning of widespread international transmission.

RESOURCES

Figure 3B is based on data from a study led by David L. Roberts at the University of Kent: **www.tinyurl.com/ytzmtpvh**.

Liebisch-Gümüş, C. (February 2021) 'Symptoms of the jet age: global air mobility and disease control in the 1960s'. Available at: **www.tinyurl.com/wd278s8a**.

Shabon, R. Z. and Sotomayor-Castillo, C. (July 2019) 'Air travel spreads infections globally, but health advice from inflight magazines can limit that', *The Conversation*. Available at: **www.tinyurl.com/4jpyh3bw**.

WHO Coronavirus (Covid-19) Dashboard: **www.tinyurl.com/bde47mys**.

KEY POINTS

- The Worldwide Air Transportation Network (WAN) provides a highly efficient system for the pandemic transmission of communicable diseases.
- On average, it took approximately 106 days (3.5 months) for the Covid-19 virus to diffuse from its index location in China to any given country of the world. The average ranged from 83 days (2.8 months) for the Western Pacific to 116 days (3.9 months) for Africa.
- International travel restrictions against Covid-19 were implemented too late to have any material effect on the establishment of pandemic transmission. More generally, disease modelling suggests that restrictions on air travel are effective in delaying, but not stopping, the international spread of communicable diseases.

Matthew Smallman-Raynor and **Sarah Jewitt** are professors in the School of Geography at the University of Nottingham. Their research interests include medical geography, health, disease and the environment.