Comparing closely related species with and without a particular characteristic, as the authors did, is a powerful way to test hypotheses about evolution. But this method requires that the data are good enough to generate evidence from which one can draw rigorous conclusions. Studying whale demography is not easy. Observing 'natural' mortality and fertility events directly is rarely possible, and the authors had to estimate demographic parameters using data from 'unnatural' mortality events — mainly from mass strandings, or from whales caught accidentally by commercial fishing activities. Lifespans, for example, were modelled from data on the age distributions of such deceased whales. Reproductive lifespans were estimated from inspections of the ovaries of these whales.

The data therefore contain biases and might involve small sample sizes; several assumptions are then required to reconstruct the demographic patterns of interest. Contemporary whale populations are also often highly affected by human activities, so their demography might not reflect patterns that existed throughout most of their evolutionary history. Although the effort and expertise needed to produce these analyses are impressive, it's worth being cautious in interpreting the results and not concluding that they provide definitive answers to the question of why menopause evolved.

The authors end by concluding that the evolution of menopause in whales and humans is an example of convergent evolution — a situation in which similar pressures of natural selection lead to the evolution of the same characteristic in notably different species. This perhaps overstates what we know about menopause in humans. We're limited in the analyses we can do to explore the evolution of menopause in our own species; comparative analysis has not been possible, given the established view that other primates don't experience menopause. Or so it was thought until last year, when a paper was published demonstrating a long post-reproductive lifespan for females in one population of chimpanzees[5]. This was surprising, given that chimps don't seem to provide much help to their grandoffspring.

Research on menopause in humans has tended to focus mainly, although not exclusively[6], on searching for evidence of helpful grandmothering, and has found this in abundance[7,8]. However, direct evidence of help between generations provides only limited support for hypotheses about the evolution of menopause. Contemporary grandmothers might help grandchildren either because menopause evolved to create helpful grandmothers, or because menopause means that older women have no choice but to invest in grandchildren rather than children. Numerous other hypotheses exist to explain menopause; one is that it is simply an artefact of declines in mortality that have extended overall lifespans while reproductive lifespans have remained the same.

Research demonstrating the helpfulness of grandmothers in our own species is useful, but perhaps more so for informing policy than for evolutionary models. Human grandmothers, like whale grandmothers[8], are important in the lives of their adult children and grandchildren, but older women are too often ignored in policy circles and public-health research[9].

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Global health

Mobile vaccine delivery is valuable in Sierra Leone

Alison Buttenheim & Harsha Thirumurthy

A trial that took mobile health services to rural Sierra Leone finds that this initiative increased COVID-19 vaccine uptake. But more must be done to expand the coverage of health services in low-income countries. **See p.612**

The global roll-out of COVID-19 vaccines was characterized by vast inequities in the pace at which high- and low-income countries gained access to vaccine doses. When low-income countries did get a reliable supply of vaccines, however, they faced a challenge common in richer countries: how to vaccinate a large proportion of the population rapidly. On page 612, Meriggi *et al.*[1] show that, in rural Sierra Leone, offering COVID-19 vaccines at temporary mobile clinics over a period of two to three days substantially increased vaccination coverage compared with that in villages that did not have mobile clinics. Their study shows that bringing essential health services closer to people who lack easy access to them is crucial for improving health-care coverage.

As with many other countries in sub-Saharan Africa, more than half of Sierra Leone's roughly eight million people reside in rural areas (see go.nature.com/3wkkrw). For these people, visiting government health facilities costs time and money, even when COVID-19 vaccination and other health services are available for free. To investigate whether taking COVID-19 vaccines to remote rural areas would increase vaccination coverage, the authors conducted a trial in 150 villages: 100 randomly selected villages received a 3-day-long mobile vaccination campaign, and 50 villages in the control group received no intervention.

Working with the health ministry of Sierra Leone and a non-governmental organization, the research team first visited the intervention villages and talked to local officials and residents about the benefits of getting vaccinated — a process typically known as community entry and mobilization. In the following two to three days, COVID-19 vaccines were transported at low temperatures from central locations to the remote villages, and made available at the centre of each village so that all eligible individuals (usually those aged 12 or older) could get vaccinated (Fig. 1).

Before any intervention, only 6% of adults in control villages and 4% of adults in intervention villages had been vaccinated. After the three-day mobile vaccination campaigns in intervention villages, however, there was a large increase in vaccination rates, with 30% of adults in those villages getting vaccinated. Assuming vaccination rates in the control group did not change in the same period, the combination of community mobilization and mobile service delivery led to a 23 percentage-point increase in vaccination rates, after controlling for statistical effects. The increase is explained partly by the greater ease with which residents of rural villages could receive vaccines without incurring substantial time or travel costs. However, the community meetings held before vaccines were brought to villages were also important: those who attended and learnt about vaccines

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Figure 1 | A pop-up COVID-19 vaccination clinic in rural Sierra Leone. Meriggi *et al.*[1] report that a trial in which mobile health services were taken to villages in remote regions of Sierra Leone improved the uptake of COVID-19 vaccines.

were more likely to get vaccinated.

Even when vaccines are offered close to home, one might wonder what more could be done to encourage people to get vaccinated. Meriggi and colleagues conducted a nested experiment in the intervention villages to evaluate two approaches to creating demand for vaccines. In 50 villages, mobilizers had one-to-one discussions with a few residents during the two days when vaccines were being delivered. In the other 50 villages, mobilizers held small group discussions with residents at local venues. Both approaches provided opportunities to promote vaccines and discuss concerns or false beliefs that people might have – albeit over only two days, which might not be long enough to overturn a person's deeply held convictions. The researchers found that, ultimately, the more intensive door-to-door approach, with its reliance on one-to-one conversations with community members, was no more effective at promoting vaccination than were the small group discussions, which might be easier for health providers to arrange.

The strongest aspect of this study is its experimental design, which provides rigorous evidence that taking COVID-19 vaccines closer to people in rural, low-income settings can result in meaningful increases in vaccination rates. The success of the approach tested in this trial mirrors that of other mobile health-service delivery schemes run by governments and health programmes. Such approaches have been used not only to promote the uptake of COVID-19 vaccines, but also to increase coverage of other essential health services. For example, COVID-19 vaccination rates increased substantially after mobile health teams were deployed in villages in South Africa's Limpopo Province (see go.nature.com/3v8hgnb). Similarly, in rural Kenya and Uganda, community health campaigns that offered malaria and HIV testing, as well as diabetes and hypertension screening, resulted in 71% of the nearly 150,000 adult residents being tested in just a two-week period[2].

Other studies support the value of making health services more accessible and convenient. In South Africa, the government introduced financial incentives designed to encourage older adults to seek COVID-19 vaccines. Yet these incentives were found to be about one-third less effective than initial estimates had indicated, after vaccine-supply factors (the number of active vaccine facilities and weekend vaccination campaigns) had been taken into account[3]. This suggests that incentives are less crucial when vaccines are readily available and easily accessible. The study by Meriggi *et al.* is a clear demonstration that, to achieve greater uptake of essential health services, governments and health organizations need to make it easier and more convenient for people to access those services.

Although the latest study suggests that mobile service delivery is much more effective in promoting vaccine uptake than are efforts that seek to create demand – such as door-to-door visits, text messages or financial incentives – investing in demand creation remains crucial. The authors attribute the relative ineffectiveness of door-to-door mobilization to either poor effort by the mobilizers or the fact that people who received mobilization might have also talked to friends and neighbours about vaccination, creating 'spillover' effects that dampened the impact of this type of intervention. An alternative explanation is that the interventions that were intended to increase demand might not have been optimally designed, and so were not targeted to the individuals who were most reluctant to get vaccinated. Developing contextually appropriate demand-creation strategies that address individuals' specific behavioural barriers is essential for their success[4].

Health providers should also be mindful of the probable need for demand-creation efforts after the initial surge of people who are least hesitant to get vaccinated – that is, after pent-up demand for COVID-19 vaccines has diminished. Ideally, approaches that both create demand and address supply should be implemented in a complementary manner. A study in rural India showed, for example, that vaccination rates in children were more than six times higher when reliable access to rural health services was combined with non-financial incentives, when compared with

a control group that had no interventions[5].

Meriggi and colleagues estimate that their mobile vaccination campaign cost US$32 per delivered dose, and note that the figure would be even less, at $23 per delivered dose, if the intervention were implemented on a larger scale. This is indeed a highly cost-effective approach to promoting COVID-19 vaccination. However, the authors' claim that their approach is more cost-effective than alternative strategies to promote vaccination, particularly demand-creation approaches such as text messages or incentives, is more questionable. Many of those strategies were tested in higher-income countries where baseline vaccination rates were much higher than in rural Sierra Leone, making it harder to achieve comparable gains in vaccination rates.

Instead, the cost-effectiveness of the interventions tested in this study should be compared with alternative approaches to vaccine delivery and demand creation in low-income countries. As the authors rightly suggest, further testing of such approaches is necessary in these countries. Equally, the potential adverse consequences of shifting scarce health-care workers from health facilities to mobile sites should be considered when mobile campaigns are implemented on a large scale. A key question to ask in these studies would be, 'Which health-care services didn't get delivered today because a mobile campaign required staffing?'

Many people in low- and middle-income countries (as well as lower-income individuals in high-income countries) face barriers in accessing affordable and convenient health-care services. During the COVID-19 pandemic, the world learnt the worth of making vaccines easily accessible. What's needed is further experimentation with decentralized health-service delivery models, a stronger emphasis on the design of demand-creation approaches and greater integration of multiple health services — from childhood vaccinations to screening for infectious and chronic diseases — into mobile health-care delivery. These approaches might prove to be a winning formula for reducing health disparities and improving population health.

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Engineering

Complex motions emerge from robot interactions

Sebastian D. Huber & Kukka-Emilia Huhtinen

An array of robots has been set up so that pushes between them produce movements that do not conform to the usual laws of motion. Fascinating behaviour emerges from these interactions: wave phenomena known as solitons. **See p.528**

Anyone taking an introductory physics course learns a few basic principles that make it easier to describe the motion of objects. These are: the energy of a moving system is always conserved; for every action there is an equal and opposite reaction, a condition known as reciprocity; and whenever the system becomes too complicated to describe, the motion can be broadly explained in terms of a linear relationship between variables. On page 528, Veenstra *et al.*[1] report a system, known as a robotic metamaterial, for which none of the above assumptions holds, and which consequently moves in an intriguing way.

What is a robotic metamaterial? Most people have a clear idea of what a robot is: a device that can autonomously perform a prescribed task. Self-flying drones that perform as well as world-champion human drone pilots[2] and quadcopters that can cope with the loss of one,

From the archive

Constantly quivering eyes let us see clearly, and a subject so large you'll need a wheelbarrow for the handbook.

50 years ago

Eye-Movements and Visual Perception. By R. W. Ditchburn — When we wish to scrutinise an object … we point our eyes towards the thing and hold them quite stationary — or so one might think. But even during periods of concentrated fixation, the eyes are never really still. They move constantly with three components of motion: a slight tremor … probably originating in the intrinsic noise of the extraocular muscles; slow drift … and intermittent, tiny, fast flicks … Our normal persistent perception of the visual world must depend on one or more of these apparently involuntary movements because if an optical device is used to hold an image more or less fixed on the retina, despite eye movements, the pattern seems to fade virtually completely within a few seconds. Isaac Newton was perhaps the first to recognise this necessity for a moving retinal stimulus. He noticed that pressing the side of the eyeball with a finger stimulates the retina mechanically, producing a coloured blob superimposed on the visual field; however "if the eye and the finger remain quiet these colours vanish in a second minute of time, but if the finger be moved with a quavering motion they appear again".
From *Nature* 22 March 1974

150 years ago

The man who jokingly said that he had to give up the study of chemistry when the science became so bulky that its Handbook required a wheelbarrow for its conveyance, expressed a truth which has been painfully felt by many scientific workers. With continual fresh additions to our knowledge, anything like a comprehensive grasp of a large science must become daily more and more difficult; but while this difficulty is generally felt, it occurs with special force in the science of chemistry. Chemistry, of all sciences, has perhaps the most unlimited capacity for development. Its subject is enormous, including the whole of nature, animate as well as inanimate.
From *Nature* 19 March 1874