Reproductive biology

Whale clues to why menopause evolved

Rebecca Sear

Why do several species of whale experience menopause, and why does the phenomenon occur at all? Analysing whale data might help to answer these questions and shed light on why menopause evolved in humans. **See p.579**

Many a menopausal person has no doubt longed to take a cold bath to ease their hot flushes, but cold waters are the natural habitat of the few confirmed non-human species that experience menopause. Menopause — identified in these species by an extended period of life after the production of offspring ends — is an unusual characteristic, shared by just a handful of species. On page 579, Ellis *et al.*[1] shed light on factors that might have driven the evolution of menopause.

Most of the known species that have menopause are whales. Five types of toothed whale (those that prey on fish, shellfish and marine mammals, unlike plankton-feeding baleen whales) seem to show long periods of post-reproductive life. These five examples are: killer whales (*Orcinus orca*), false killer whales (*Pseudorca crassidens*), short-finned pilot whales (*Globicephala macrorhynchus*), beluga whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*). Many other toothed whales, including dolphins (members of the family Delphinidae) and porpoises (members of the family Phocoenidae), do not.

By comparing the characteristics (Fig. 1) of toothed whale species that do, and do not, experience menopause, Ellis *et al.* find support for two hypotheses for why menopause evolved. One is that it allows post-menopausal females to help their younger relatives; the other is that it limits competition for resources between generations — for example, by reducing the number of mouths that need to be fed.

The evolution of menopause is considered a puzzle by many biologists[2]. An intuitive assumption is that reproducing until the end of a lifespan should result in greater reproductive success — more genes being passed on to future generations — than would stopping reproduction many years, or even decades, before death. This assumption is simplistic. Passing genes on to future generations isn't just about generating offspring: it's also about producing grandoffspring (and great-grandoffspring, and so on). Investing in offspring and grandoffspring to make sure that they survive to adulthood and produce offspring themselves might sometimes be a better strategy than would continuing to produce offspring of one's own. This proposed explanation for the evolution of menopause is known as the grandmother hypothesis[3].

An alternative hypothesis, although the two are not mutually exclusive, is that menopause evolved to reduce competition for resources between generations[4]. Species that experience menopause tend to have long lifespans and to live in groups containing multiple generations. Although group living has many benefits, it necessitates having to share limited resources. Continuing to produce offspring that will compete with grandoffspring for resources might sometimes result in fewer descendants than would giving up on reproduction. Both cooperation and competition between post-menopausal females and their younger relatives have therefore been proposed to explain the evolution of menopause.

To test these hypotheses, Ellis and colleagues searched published scientific literature for data that could be used to reconstruct whale mortality, lifespan and fertility patterns. They then compared these patterns in species with and without menopause. Toothed whales have relatively long lifespans, with many species capable of living for several decades, and the results indicated that species with menopause typically live longer than do those without. The reproductive lifespan (during which females can produce offspring) was around the same in both groups, however.

This means that, in species with menopause, there is a greater likelihood that mothers, adult offspring and grandoffspring will be alive at the same time, resulting in a substantial overlap between generations. But these mothers and daughters are no more likely to be reproducing at the same time than are those in species without menopause; the reproductive overlap between them is about the same in both groups. Thus, in species with menopause, older females have more opportunity to help their offspring and grandoffspring, but there is less opportunity for competition between generations. This is because whale grandmothers spend part of their later life not producing offspring, which would compete with grandoffspring for resources. Altogether, these demographic patterns suggest that both the cooperation and the competition hypotheses for the evolution of menopause are plausible.

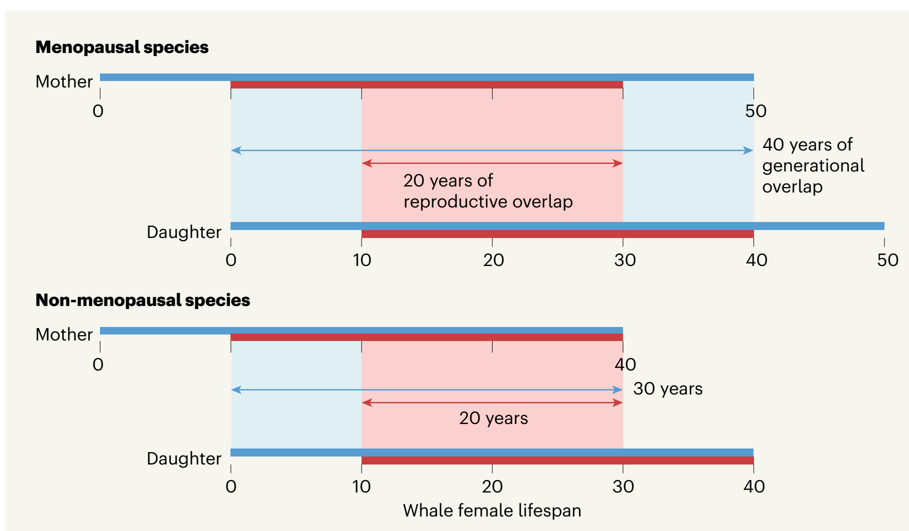

Figure 1 | The timing of reproduction and generational overlaps in whale species that do or don't have menopause. Ellis *et al.*[1] compared data for whale species regarding lifespan (blue bar) and the window of female reproduction (red bar). The authors report that species with menopause typically live longer than do those without, meaning that species with menopause have a longer overlap between generations. The reproductive lifespan is similar, irrespective of whether menopause occurs. Older females in species that have menopause can provide aid to family members during the period of generational overlap, but restricting the window of reproductive overlap reduces competition between offspring and grandoffspring for resources (hypothetical numbers plotted to indicate the general trends).

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