Look, no dad!

We're discovering many females can reproduce all by themselves. So why even bother with males, wonders Helen Pilcher

CHARLES SMITH

JUST over a decade ago, a baby hammerhead shark slipped silently from its mother's belly into the welcoming waters of the aquarium at the Henry Doorly Zoo in Nebraska, creating ripples that are still spreading around the world. The mother had had no contact with male sharks for at least three years, and DNA tests confirmed that the pup had no father. "It was unprecedented," says shark geneticist Demian Chapman of Stony Brook University in New York, who carried out the paternity test. It was the first virgin birth ever confirmed in a shark.

The pup's unexpected arrival was swiftly followed by an unexpected departure: it was killed by a stingray only a few days later. Yet it has since become apparent that the pup was not as singular as first thought. In the past few years, many other vertebrates have been shown to produce offspring by virgin births. All of which begs the question: why do we animals bother with males at all?

Until recently, virgin births in animals that reproduce sexually were seen as an anomaly – something that simply does not happen in the wild. "The dogma is that this is a captive syndrome only seen in animals in zoos and aquaria," says Warren Booth of the University of Tulsa in Oklahoma.

This view is understandable given that in mammals, virgin birth – or parthenogenesis – is abnormal and extremely rare. Eggs do sometimes start developing without being fertilised by a sperm, but the embryos usually die or turn cancerous. One boy is known to be partly the result of a "virgin birth" – his body is a chimera of normal cells and cells formed by parthenogenesis. But full virgin births do not occur naturally in mammals because our paternal and maternal genes are stamped with different chemical marks or "imprints". Without both sets, gene activity is disrupted.

Aside from mammals, though, virgin births are turning out be surprisingly common. The list of vertebrates known to be able to reproduce parthenogenetically as well as sexually now includes several shark species, boa constrictors, turkeys and Komodo dragons. The biggest surprise is that it seems to happen in the wild, not just in captivity.

Last year, Booth and his colleagues analysed 59 litters from two species of North American pit viper, caught when they were already pregnant (*Biology Letters*, vol 8, p 983). Two of the litters were virgin births – the first recorded cases in the wild (one of these snakes and its offspring are pictured above). "We think this type of reproduction is a lot more common in reptiles and certain other animals than was previously thought," says Booth. "It's really changing the way we think about reproduction in reptiles."

Even more astonishingly, the pit vipers were caught in areas with plenty of males. So these snakes do not seem to be reproducing this way only as a last resort when mates are scarce.

Indeed, as evolutionary biologists and any girl who has ever dumped her boyfriend will tell you, there are many benefits to doing away with males. In female-only species, every individual can produce offspring, so the population can grow faster than species with males and females. Time spent looking for love means less time looking for food, and there is the risk of catching a nasty disease during mating or being eaten while distracted. To top it all, sex randomly shuffles the genetic deck creating new, potentially flawed blends of genes when the old ones tend to be working perfectly well. All of which makes the preponderance of sex in the animal kingdom something of an enigma.

So can vertebrates manage without males? The first hint they can came in 1932 with the discovery of an all-female species of fish found in southern Texas and northern Mexico: Amazon mollies (*Poecilia formosa*), named after the legendary tribe of female warriors.

This baby pit viper is with its only parent – and is a clone of her

Even though there are no male Amazon mollies, it turns out that the females still need males. Their eggs will not develop unless stimulated by sperm. So they court and mate with males from any one of several related species, but the offspring inherit only the mother's DNA – a phenomenon called gynogenesis. This peculiar arrangement means Amazon mollies can only live in the vicinity of one of these other species.

Altogether, around 90 female-only species of fish, amphibians and reptiles have now been discovered, but like the molly most still need males of other species to be present. The rest, including some whiptail lizards and geckos, seem to thrive without any male involvement at all, though they do show signs of mating behaviour: the whiptail lizards pseudocopulate with other females of the species, earning them the nickname "lesbian lizards". "But in my view that's no different to two dogs mounting. It's about establishing dominance," says Peter Baumann of the Stowers Institute for Medical Research in Kansas, Missouri, who studies parthenogenesis.

So a few species do not need males at all. The question is why the number is so low, given that in theory females that reproduce only by parthenogenesis should produce more offspring and outcompete sexual ones. While much remains to be discovered, there appear to be several reasons why the male of the species is needed. One could be that all-female species soon go extinct.

All-female species

Models suggest that unisexual species can do fine in the short term, but in the long run they run into trouble as their genomes stagnate. Without the ability to reshuffle their genome and get rid of harmful mutations, their survival time is likely to be between 10,000 and 100,000 generations (*Evolution*, vol 44, p 1725).

The whiptail lizards and geckos have not reached this limit yet, but some all-female species are much older. The Amazon molly is about 280,000 years, or 800,000 generations old. And it is a mere whippersnapper compared with another gynogenetic species, the *Ambystoma* mole salamanders that live around the Great Lakes region of North America. This all-female species appeared around 5 million years ago, so it has survived for about 1 million generations. How do these species manage it? They cheat by stealing DNA.

After they mate with males from other species, the DNA in the sperm is usually discarded, but every now and then part of it is incorporated into the genome of the offspring. Mollies occasionally steal fragments of chromosomes, while mole salamanders plunder entire sets. Jim Bogart at the University of Guelph in Ontario, Canada, ›

A TURKEY'S TALE

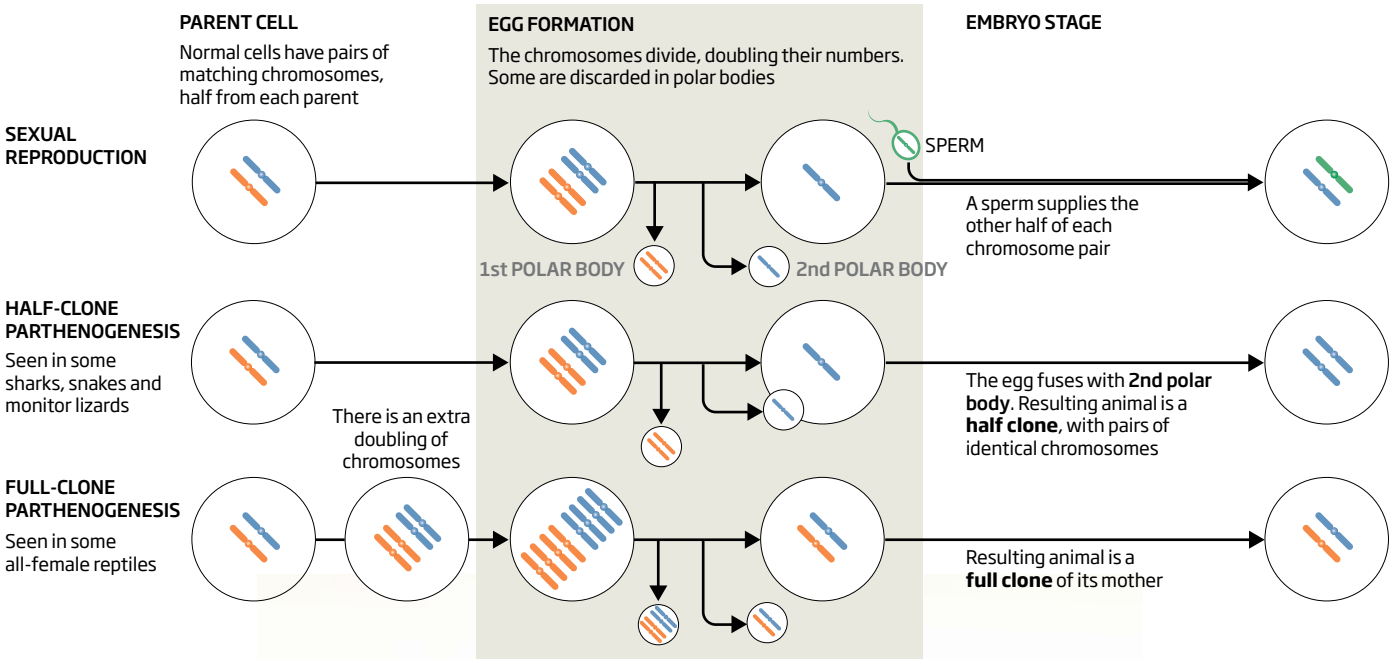
Virgin birth appears to be an extremely rare phenomenon in birds. There have been anecdotal reports of it in chickens, but these have not been confirmed.

The only bird that is undoubtedly capable of producing healthy offspring this way is, appropriately enough, the bird eaten to celebrate a mythical virgin birth. Yes, the turkey.

In the 1950s, researchers at the Beltsville Agricultural Research Center in Maryland discovered Beltsville Small White turkeys sometimes produced male offspring by parthenogenesis. Most were able to develop and reproduce normally. The researchers managed to increase the frequency of such births by selective breeding.

Doing it for themselves

There are different ways in which virgin births can occur, and not all produce a full clone of the mother



has coined the term "kleptogenesis" to describe the process. He think it allows the females to get hold of genes that are better adapted to their current environment and thus compete with sexual animals.

The unisexual salamanders can dump entire sets of chromosomes, too, which helps prevent the build-up of harmful mutations, Bogart says. "The system is very cool and is driven by natural selection – when a clone runs into problems, new clones evolve."

So unless all-female species can nick genes from males, they may not survive long. What's more, the creation of a unisexual species also seems to require unusual circumstances. There is no evidence that a single sexual species can slowly evolve into an all-female one. Instead, every unisexual species discovered so far, with just one possible exception, was created instantaneously by two species interbreeding. The unisexual whiptail lizard *Aspidoscelis neomexicana*, for example, was formed in one fell swoop when a male *A. inornata* had sex with a female *A. tigris*. One mating was all it took to instantly create a new species.

This is, as you might expect, incredibly rare: most interspecies hybrids are either sterile or can reproduce sexually with one or both parent species. But there is no doubt it does happen. In 2011, Baumann's team managed to create a new unisexual species in the lab by fertilising eggs from one unisexual whiptail lizard species with sperm from a sexual species (*PNAS*, vol 108, p 9910).

Some species, like this mole salamander, are entirely female

JOEL SARTORE/NGS

This merging of two different genomes may help unisexual species get off to a good start, by giving them the hybrid vigour seen when plants are crossbred. What's more, these hybrids reproduce in a special way. There are different forms of parthenogenesis, producing either half clones or full clones (see diagram, above). Species that have managed to ditch males, like the unisexual whiptail lizards, produce full clones.

Abandoning sex

Animals that only occasionally resort to parthenogenesis almost always produce half clones, however, and these are likely to suffer from severe inbreeding because they get a double dose of any harmful mutations. This could be why few survive. A zebra shark in the Burj Al Arab aquarium in Dubai, for instance, produced more than a hundred parthenogenetic eggs over several years, but just 4 pups survived. So abandoning sex does not offer the big advantage in terms of producing more offspring that theory suggests.

Last but not least, virgin births do not always produce daughters as you might expect. In birds and some reptiles, the females possess both male and female sex chromosomes, which means in theory they could produce both males and females by parthenogenesis. In practice, boa constrictors only seem to have female virgin births – but pit vipers and turkeys have only been observed to have male virgin births (see "A turkey's tale", page 35).

In these species, then, far from being a way to do without males, virgin birth is a way of making more of them. "The theory is that if you have a lone female snake on an island, she can reproduce asexually to produce a male, and then breed back with it sexually to produce more offspring," says Booth. We do not know if this is the case yet. Booth is keeping a watchful eye on his pit viper offspring, to see if and how they reproduce.

But the evidence so far suggests that males can relax. Some females may be able make babies without them, but sooner or later their descendants have to resort to having sex with males again if they want to avoid extinction. Now there's a boost for the male ego. ■

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