SUSTAINABILITY

How is the gender of some reptiles determined by temperature?

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Alex Quinn, a Ph.D. candidate at the Institute for Applied Ecology at the University of Canberra in Australia, sorts this quandary out for us.

Sex-determining mechanisms in reptiles are broadly divided into two main categories: genotypic sex determination (GSD) and temperature-dependent sex determination (TSD).

Species in the genotypic group, like mammals and birds, have sex chromosomes, which in reptiles come in two major types. Many species—such as several species of turtle and lizards, like the green iguana—have X and Y sex chromosomes (again, like mammals), with females being "homogametic," that is, having two identical X chromosomes. Males, on the other hand, are "heterogametic," with one X chromosome and one Y chromosome. Other reptiles governed by GSD have a system, similar to one found in birds, with Z and W sex chromosomes. In this case—which governs all snake species—males are the homogametic sex (ZZ) and females are the heterogametic sex (ZW).

In temperature-dependent sex determination, however, it is the environmental temperature during a critical period of embryonic development that determines whether an egg develops as male or female. This thermosensitive period occurs after the egg has been laid, so sex determination in these reptiles is at the mercy of the ambient conditions affecting egg clutches in nests. For example, in many turtle species, eggs from cooler nests hatch as all males, and eggs from warmer nests hatch as all females. In crocodilian species—the most studied of which is the American alligator—*both* low and high temperatures result in females and intermediate temperatures select for males.

A widely held view is that temperature-dependent and genotypic sex determination are mutually exclusive, incompatible mechanisms—in other words, a reptile's sex is never under the influence of both sex chromosomes *and* environmental temperature. This model indicates that there is no genetic predisposition for the embryo of a temperature-sensitive reptile to develop as either male or female, so the early embryo does not have a "sex" until it enters the thermosensitive period of its development.

This paradigm, though, has been recently challenged, with new evidence now emerging that there may indeed be both sex chromosomes and temperature involved in the sex determination of some reptile species. Apparently, in animals where both occur, certain incubation temperatures can "reverse" the genotypic sex of an embryo. For example, there is an Australian skink lizard that is genotypically governed by X and Y sex chromosomes. A low incubation temperature during the development of this lizard's egg reverses some genotypic females (XX) into "phenotypic" males—so that they have only functioning male reproductive organs. Therefore, in this species, there are both XX and XY males, but females are always XX. A slightly different example of this temperature-induced sex reversal is found in an Australian dragon lizard, which has the ZW system of sex chromosomes. In this species, high incubation temperature during egg development reverses genotypic males (ZZ) into phenotypic females; so females can be ZZ or ZW, but males are always ZZ.

Reptiles in which both incubation temperature and sex chromosomes interact to determine sex may represent "transitional" evolutionary states between two end points: complete GSD and complete TSD. It is quite possible that there are other species of reptiles with more complicated scenarios of temperature reversal of chromosomal sex. There are certainly many known examples of fish and amphibians with GSD, in which both high and low incubation temperatures can cause sex reversal. In these cases, all genotypes (from ZZ and ZW to XX and XY) are susceptible to reversal by extremes of incubation temperature.