Behavioural ecology

# Coots count

Malte Andersson

**American coots distinguish their own eggs from the eggs that other female coots lay in the same nest. They use a variety of tactics to minimize the adverse reproductive effects of the parasitic behaviour.**

Cuckoos are infamous for laying their eggs in the nests of other bird species: the unfortunate hosts raise the parasitic chicks, reducing or even nullifying their own reproductive output. It is less well known that 'brood parasitism' among females of the same species is common in certain fishes, insects and birds[1]. In this conspecific brood parasitism, where females parasitize others of their own species, the host parents will bear a high cost when they feed chicks that are not their own.

Ways of reducing these costs are therefore expected to be favoured by natural selection. On page 495 of this issue, Bruce Lyon[2] describes how an aquatic bird, the American coot *Fulica americana* (Fig. 1), uses several remarkable behavioural tactics to this end. In this species, a parasitic chick that survives usually does so at the cost of a host chick. But the host parents can often identify the eggs of parasites, and reject or otherwise disadvantage many of them.

With some exceptions[3–6], discrimination against parasitic eggs seems to be a rare defence in conspecific brood parasitism. In many species, hosts may not be able to tell the difference between their own and alien eggs[1]. Coot eggs vary considerably in colour, however, and Lyon finds that coots can not only often distinguish their own eggs from those of a parasite, but — remarkably — can count them, disregarding the number of parasitic eggs in the clutch. This surprising cognitive feat makes good adaptive sense. Like many other birds, coots are indeterminate layers[7]; that is, they regulate egg production using external stimuli, such as the number or surface area of the eggs already in the nest, to control egg development and final clutch size. If the parent cannot distinguish between its own and parasitic eggs, the latter can cause it to stop egg production too early, reducing the final clutch size below that necessary for its own maximum reproductive success.

As with most birds' eggs, there is little difference in surface texture between eggs laid by different female coots. So although responses to a tactile stimulus cannot be completely ruled out, it seems unlikely that this is the distinguishing cue. By contrast, to the human eye, the coloration of coot eggs — a conspicuous pattern of dark spots on a brown background — varies considerably among females (Fig. 1, inset). Visual cues therefore seem to offer ample scope for egg discrimination. Lyon[2] indeed found that the visual differences between eggs of host and parasite were larger in nests where parasitic eggs were rejected than where they were accepted. For the host to be able to reject a parasitic egg, therefore, it seems that there must be a large enough difference in the eggs' appearance.

Lyon compared coot pairs that accepted parasitic eggs ('acceptors') with pairs that rejected them ('rejectors'). He found that acceptor females produced a lower final number of their own eggs. Rejector females, however, did not reduce their own final clutch size. Evidently they recognized and counted their own eggs, avoiding a maladaptive reduction in the number of their own eggs in response to the added parasite eggs. Later on, rejector hosts discarded parasitic eggs by burying them under nest material, or moved them to peripheral positions in the clutch. The consequence was to prevent or delay the hatching of parasitic chicks, so reducing competition with the host's true offspring. On average, such behaviour halved the effect of parasitism on the reproductive success of the hosts.

Some aspects of this defensive behaviour raise more questions. Why do coots eject cracked or rotten eggs from the nest, but bury parasitic eggs? And why do they move some parasitic eggs to the periphery of the clutch rather than reject them altogether? Lyon suggests that the latter behaviour may represent an intermediate form of defence, used when the bird is uncertain whether the egg is parasitic.

From an ecological perspective, Lyon's results are striking in what they tell us about the costs of brood parasitism, and defences against it. They also shed light on cognition and counting by animals, in a natural context where reproductive success is at stake. There is suggestive evidence[8] that counting may be important in such circumstances. But it is rarely as clear as here.

Usually, the number of items counted in natural situations is small, as is the case for coots counting their eggs. With proper experimental training, however, pigeons and rats have made surprisingly accurate choices in complex tasks that involve counting to up to several dozen[9]. Many animals apparently have a brain wiring that in the right circumstances can support competent counting without verbal symbolic representation of numbers. Lyon's findings provide a fascinating example of how this capacity is put to good use in the wild. Who would have expected that from a birdbrain?

There are plenty of open questions. For example, what is the genetic basis and heritability of the visual appearance of eggs, and does this have consequences for parasitism involving relatives? Does parasitism create

BRUCE LYON

Figure 1 **Coots in a flap. These birds fight over territorial borders, territory size setting the limit for the number of chicks that can be successfully fed by the parents. Hence the evolution of brood parasitism to bypass this constraint. The inset shows a parasitized nest — the two darker eggs are the ones laid by a brood parasite.**

selection for increased variability in egg coloration, making it easier to detect parasitic eggs[5]? A combination of Lyon's incisive field techniques with genetics, and with molecular determination of parasitism and parentage[10,11], seems likely to provide further insights into the cognitive and tactical aspects of brood parasitism and reproductive behaviour. ■

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Nuclear physics

# Into the fission valley

Peter Möller and Arnold J. Sierk

**Why are new elements difficult to make? Fusion of two nuclei to produce heavy elements seems to be hindered by a competing process of 'quasi-fission'. New work builds a more complete picture.**

On Earth, elements heavier than uranium do not exist in easily measurable quantities, because they become increasingly unstable against radioactive decay. Some heavier elements can be artificially created through the collision and fusion of other nuclei, and over the past 60 years about 20 new elements have been added to the periodic table — up to an atomic number of at least 110. But fusion becomes less successful when the projectile and target nuclei are chosen to form a product with nucleon number, *A*, greater than 220 (more than 90 protons and 130 neutrons). For example, in some experiments[1] only about one out of $10^{18}$ nuclei incident on a target leads to the creation and detection of the desired new element.

In *Physical Review Letters*, Hinde, Dasgupta and Mukherjee[2] present a detailed analysis of this inhibition of fusion near $A = 220$. They made a careful comparison of fusion cross-sections (or probabilities) from their own experiment on the reaction $^{16}O + {}^{204}Pb$ with other experiments on $^{40}Ar + {}^{180}Hf$, $^{48}Ca + {}^{172}Yb$, $^{82}Se + {}^{138}Ba$ and $^{124}Sn + {}^{96}Zr$, all of which lead to the same compound system, $^{220}Th$. The results show that it is much more difficult to make $^{220}Th$ with more symmetric combinations of target and projectile than with the most asymmetric combination ($^{16}O + {}^{204}Pb$) — specifically about ten times more difficult. Hinde *et al.* propose that this is due to competition with the process of 'quasi-fission'. Colliding nuclei form a composite at the onset of the fusion process, but the composite may break up, or undergo fission, before fusion is complete. True fission occurs after the formation of an equilibrated compound nucleus; quasi-fission results from the much faster breakup of a partially fused composite.

Today's theories of heavy-ion collisions are mainly macroscopic; the energy of the colliding system can be written as a sum of the repulsive electrostatic energy and the attractive nuclear energy. After the colliding nuclei touch, these energies must be calculated for the combined system as functions of its shape. The resulting 'energy landscape' (a multi-dimensional potential-energy surface in deformation space) has a strong influence on the dynamics of the fusion process.

In macroscopic models, the energy landscape changes relatively slowly with proton and neutron number and with deformation of the shape of the nucleus away from a simple sphere. But microscopic effects, which arise because the protons and neutrons in the nuclei obey quantum-mechanical laws, vary much more rapidly as the neutron and proton numbers and the shape change, sometimes producing large differences between the behaviour of systems with only slightly different nucleon number. Microscopic effects are not often included in theoretical studies of nuclear collisions, but we believe that they should be considered more carefully. There are other factors, too: how dissipation converts the kinetic energy of the projectile into internal excitation energy of the fusing system; and the effect of the relative orientation of target and projectile if one or both of them are deformed (around 50% of stable nuclei are not spherical).

In their paper, Hinde *et al.*[2] consider various explanations for the inhibition of fusion seen in the data. First, they discuss the idea of the 'extra push' — a colourful misnomer used to describe a dynamical threshold. For heavy compound systems, extra kinetic energy (more than is needed to bring the nuclei into contact after overcoming their electrostatic repulsion) is required for them actually to fuse and form a single nucleus. A good analogy is a skier crossing a mountain range, starting out with some initial energy. For

## 100 YEARS AGO

**Concerning the recently discovered heat emission from radium, it is perhaps worth noting that it appears to be connected with, and is probably an immediate consequence of, the remarkable observation by Rutherford that radium emits massive positively-charged particles, which are probably atoms, with a velocity comparable to one-tenth of the speed of light… Because it is easy to reckon that the emission of a million heavy atoms per second, which is a small quantity barely weighable in a moderate time such as a few weeks (being about the twentieth part of a milligramme per century), with a speed equal to one-tenth that of light, would represent an amount of energy equal to one thousand ergs per second; that is to say, would correspond to heat enough to melt a milligramme of ice every hour. And inasmuch as these atoms are not at all of a penetrating kind, but are easily stopped by obstacles, they would most of them be stopped by a small thickness of air, and their energy would be thus chiefly expended in the immediate proximity of the source, which source would thereby tend to be kept warm.**
**From *Nature* 2 April 1903.**

## 50 YEARS AGO

**Before the War one could make materials artificially radioactive by bombardment in big machines like cyclotrons, or by using relatively weak neutron sources. In the cyclotron, one can generally only use one target at a time and the irradiation is therefore costly. The weak neutron sources induce only weak activities. Therefore only a few research workers profited from the radioisotopes which one could produce in these ways. The situation changed suddenly with the discovery of fission of uranium in 1939. This discovery showed that chain reactions were possible in which more neutrons are created than used. Accelerated by war research, the first chain-reacting atomic pile was working on December 2, 1942, in Chicago… New radioisotopes were quickly discovered and the chart of radioactive isotopes started to expand. To-day, there are more than six hundred radioactive isotopes, of which, however, only some hundred can be made conveniently in an atomic pile. For most elements there is at least one usable radioactive isotope. The only notable exceptions are the two elements nitrogen and oxygen for which no convenient radioactive isotope exists.**
**From *Nature* 4 April 1953.**