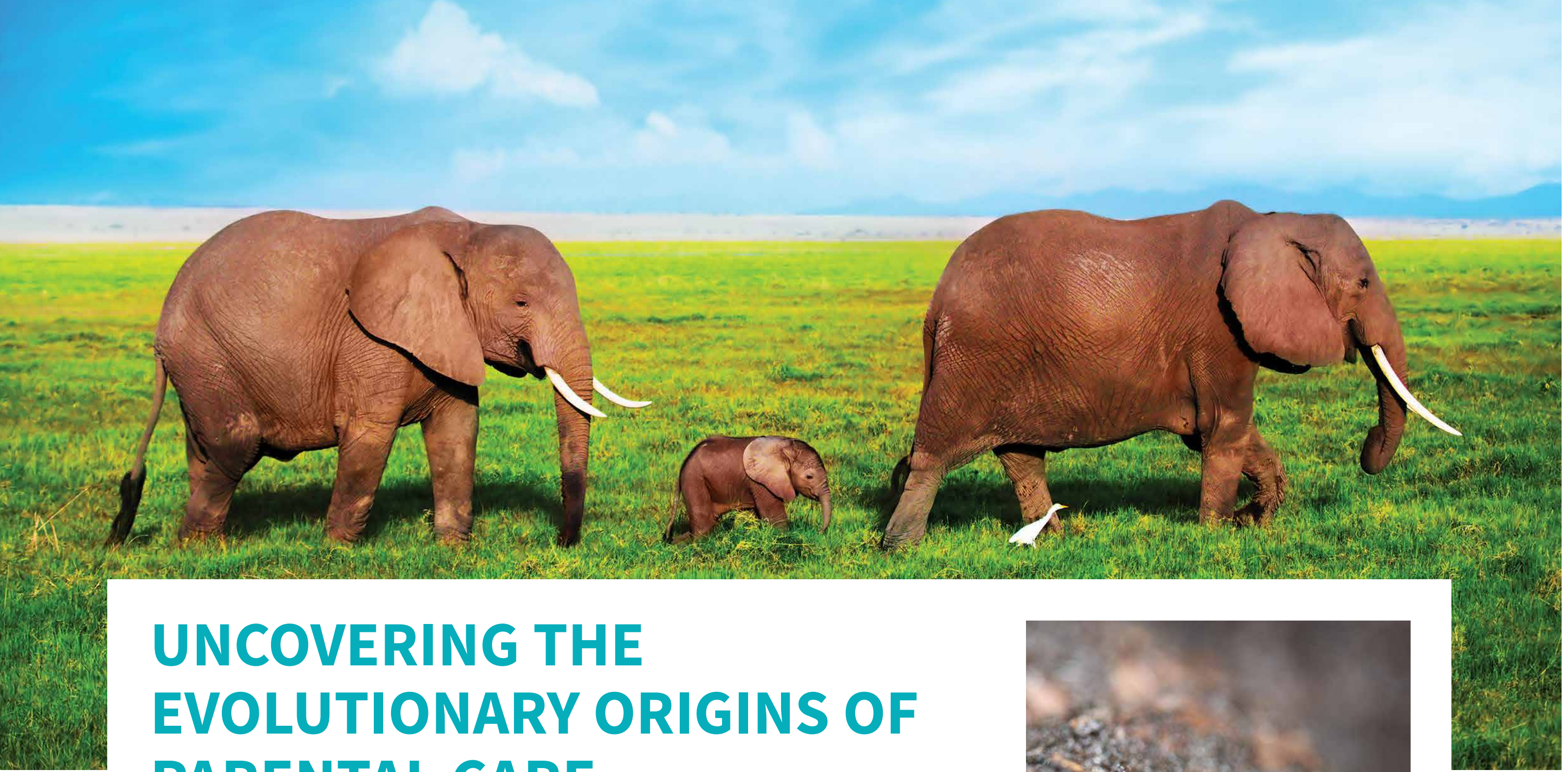
Uncovering the **Evolutionary Origins of Parental Care**

Professor Allen J. Moore



UNCOVERING THE EVOLUTIONARY ORIGINS OF PARENTAL CARE

Parental care is relatively uncommon in the animal kingdom, and most young are left to fend for themselves at birth. However, parenting behaviours have evolved multiple times in the history of life and are seen in diverse groups of animals. In recent years, biologists have begun to understand the genetic underpinnings of parental behaviour in the hope of illuminating parenting's mysterious evolutionary origins.

It's Expensive Being a Parent

Human babies are decidedly the neediest young in the animal kingdom. They require intensive parental care for years, as they cannot walk, feed themselves, or protect themselves until much later in life. Often people find it surprising that this is seldom the case in other animals. In fact, parenting is a relatively rare phenomenon across the animal kingdom. The offspring of most species get no more than the genetic contributions of their mothers and fathers, before emerging into the world as independent beings required to feed and protect themselves to survive.

Why is parenting so rare? Because it's expensive! Any human parent knows that having a baby is no cheap endeavour, but in evolutionary terms, parenting is a costly behaviour across the animal kingdom. The currency of evolution is fitness – your ability to spread your genes. The more grandkids and great-grandkids you have, the more evolutionarily fit you are so taking care of your babies would seem to make sense. However, offspring that require care can cost parents food and energy resources, make them more vulnerable to predators, and limit their ability to reproduce again quickly. Taking care of your babies limits how many you can have.

While it may be rare, examples of parental care are scattered across almost every branch of the taxonomic tree. Once presumed to be unique to large brained mammals and birds, researchers have discovered forms of parental behaviour in animals as simple as insects. This indicates that parenting has evolved multiple times in the history of animal life on earth. Thus, while parenting may be an evolutionarily costly behaviour, for some species the benefits of parental behaviour outweigh the costs.

While biologists have a good grasp on 'why' parenting is expected to evolve in certain conditions, less is known about the 'how'. Knowing what has to change through evolution should also inform us on why it changes. Ultimately, what changes is genes as evolution is defined by the changes in genetic makeup of populations. But is it new genes that have to evolve, or does evolution change the existing genes? It has only been within the past 15 years that technological advances have begun to allow researchers to unravel the genetics underlying parental behaviour. Professor Allen J. Moore is one researcher who has dedicated his career to uncovering the genes that underlie parental behaviours and their evolution.

A New Model Parent

Historically, biologists have focused on mammals and birds when studying parental care, particularly in the limited research focused on the genetics of parenting behaviour. Mammals may seem like a logical choice since parenting is more widespread amongst this group. However, beyond laboratory rodents there are few mammalian species whose genetics we understand well enough to enable us to pin down the complex genetic contributions

to parenting behaviours. Mammalian studies using rodents tend to focus only on maternal behaviours, since females tend to do the heavy lifting in parenting as they provide the food. Many species of bird engage in balanced mother/father parenting workloads, because both are potentially equally capable of care, but their genetics are less clearly mapped out. Birds can also be more difficult to study in the laboratory, as many behaviours observed in the wild are altered in captivity. In addition to the potential for behavioural changes, both mammals and birds require large amounts of space, specialised care, and a great deal of time to observe multiple generations in the laboratory.

The ideal organism to study parenting behaviour evolution would need to meet several criteria. First, the animal needs to be a good parent, demonstrating a range of easily observable parenting behaviours. To understand sex differences, both males and females should have the potential to contribute to offspring care. In depth genetic information must be available for the chosen animal, so that unique genetic pathways can be analysed. Finally, it needs to reproduce quickly and reliably, with minimal behavioural effects of captivity. In a perfect world, this animal would also be easy and inexpensive to care for in a small space.

These criteria may sound impossible to meet, but Professor Moore found the ideal model organism for studying the evolution and genetics of parental behaviour: *Nicrophorus vespilloides*, the burying beetle. Burying beetles are excellent parents – before mating they find an ideal animal carcass, lay eggs nearby, then carefully go about preparing the carcass for their developing eggs by burying it underground and stripping it of its fur or feathers. Once larvae hatch, parents feed the begging babies pre-digested meat until they can feed themselves, while continuing to clean the carcass of mould and defend it from other insects. Burying beetle babies eat fresh – not rotting – meat, so the parents are essential. Moreover, the parents partially digest the carcass and regurgitate food to their begging young. Both males and females engage in parental care, sometimes as single mothers or fathers, and sometimes as a pair. Professor Moore's team has sequenced the complete genome of the burying beetle and has a full repertoire of genetic tools at their disposal. The beetle's entire life cycle from newly hatched egg to sexually mature adult is extremely fast, taking only about a month, and there is no observable difference in behaviour between beetles in the wild and beetles in the lab. To top it all off, burying beetles are simple to care for in even the most basic of facilities. Professor Moore and his team have been working to build this fascinating insect into a recognised 'model parent' in biology for nearly 20 years, and in doing so, have shed light on many novel facets of parenting genetics and evolution.

Mother *vs.* Father

One unique trait that burying beetles share with humans is flexibility in family structure. In most animals that show parenting behaviours, the roles of the mother and father are relatively set in stone, and alterations in the family structure cause the young to suffer. For many mammals, leaving the baby alone with the father can be a death sentence, as mammal fathers are often unable and/or unwilling to care directly for their young. Not so with burying beetles; it is common for a mating pair to work together to co-parent their larvae, but both single mothers and single fathers will dutifully care for a brood on their own if the other parent departs for any reason. In their research, Professor Moore and colleagues demonstrated that offspring raised by one parent are just as successful as offspring raised by both parents, and larvae raised by a single burying beetle dad do just as well as larvae raised by a single mother or both parents.

Instances of truly equal maternal and paternal contributions to offspring rearing are even rarer in the animal kingdom than parenting itself. While in some fish and bird species fathers take the primary care role, most often it is the mother that makes the biggest contribution to caring for young. In most mammalian species, offspring do equally well when cared for by the mother alone as when cared for by both parents. Because of this, it has been hypothesised that dual care evolved more as a way for males to protect and secure valuable females, than for the benefit of the offspring. While burying beetles appeared to be equal contributors at the surface, Professor Moore intuitively knew that family dynamics are often more complex, and sought to dig deeper into the family structure of burying beetles. He started by performing a large-scale behavioural and genetic study of over 250 beetle family units that would allow him to fully tease apart the roles of the mother and father in burying beetle parenting.

First, Professor Moore allowed beetles to freely pair and form family units, carefully observing behaviour and time spent parenting. Interesting behavioural patterns emerged: the level of attention that both paired mothers and single mothers gave their offspring was nearly indistinguishable, and single fathers were just as attentive as mothers. However, paired fathers spent much less time parenting than single dads, allowing the mother to do most of the work when she was available. While it was true that offspring of single males did just as well as those in other family situations, single father families were much less common that single mother families, because males were ten times more likely to abandon their families than females.

To understand what was going on beneath the surface, Professor Moore and his team looked at the gene expression

patterns of male and female burying beetles before, during, and after parenting, and compared this to the gene expression profiles of unmated beetles of the same age. They found that the beetles expressed genes differently while caring for offspring, but had similar expression patterns to non-parents before and after rearing young. This suggests that different genes are turned on and off when parenting. Unsurprisingly, there was little difference between the gene expression profiles of paired and single mothers. However, single and paired males were drastically different. Single father gene expression mirrored the profiles of mothers, while paired father profiles were more similar to unmated beetles. This means that single dads not only behave more like mothers on the outside – their gene expression shifts to support caring behaviour on the inside. Regardless of family structure, once their larvae mature, both sexes go back to pre-mating gene expression patterns. This finding highlights the flexibility of burying beetle family structure – males are biologically capable of rising to the occasion when necessary to ensure offspring survival.

Becoming a Parent

The discovery that the gene expression profiles of burying beetles is flexible with regard to parenting could shine light on how parenting evolved in burying beetles in the first place. Expression profiles of parents only differ while they are actively parenting, but before mating and after their larvae mature, their gene expression patterns are the same as non-parents. Since parenting itself encompasses a complex suite of behaviours, Professor Moore decided to focus on genes that are keystones in gene networks.

A key component of burying beetle parenting behaviour is regurgitating partially digested food for newly hatched larvae. Professor Moore hypothesised that to perform this behaviour, beetle parents would need to suppress their own urges to eat. To examine genetic pathways associated with this behaviour, Professor Moore opted to target neuropeptide F (NPF), a gene involved in regulating hunger with the capability to influence many other gene expression networks associated with both feeding and social behaviour. This gene is found in all organisms, including humans (where it is called neuropeptide Y), and plays a central role in the motivation to feed. As he predicted, they found that NPF expression was reduced during parenting stages, but returned to normal levels once offspring matured. This provides insight into how a highly complex behaviour may evolve simply by changing the expression of a single gene.

Through further analysis of the brain chemistry of burying beetles at different stages of parenting, Professor Moore and his team have identified additional candidate neuropeptides that have not previously been associated with parenting. Like NPF, these neuropeptides are predicted to play a role in pathways associated with complex behavioural changes. These findings demonstrate that it is possible to predict and identify likely targets of evolutionary selection, and reinforce the concept that changes in the expression of one gene are often sufficient to induce complex, novel behavioural states. These networks of genetic changes lend flexibility to behavioural systems and provide a basis for the dynamic range of behaviours an individual is capable of under different conditions.

Parenting is certainly a complex set of behaviours, but Professor Moore's work with the burying beetle has begun to reveal how such a multifaceted process may evolve through even minor changes in key parts of a gene network.

Meet the researcher

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Professor Allen Moore began his education at Arizona State University, graduating with a BSc in Zoology in 1982. He went on to complete a PhD in Environmental, Population, and Organismal Biology at the University of Colorado in 1988, during which he was awarded a Behavioural Genetics Trainee fellowship by the National Institute of Mental Health. He went on to complete postdoctoral research in neurobiology at both Northwestern University Medical School, Chicago, and Washington University School of Medicine, St. Louis. Professor Moore has served as a Professor at many prestigious universities, including the University of Kentucky, Lexington, the University of Manchester, UK, and the University of Exeter, UK, and worked as a Program Director in Population Biology for the National Science Foundation. He founded his laboratory at the University of Georgia in 2011, where he currently serves as a Distinguished Research Professor in the Department of Genetics.

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FUNDING

NERC, UK
NSF, USA

REFERENCES

CB Cunningham, M Badgett, RB Meagher, R Orlando and AJ Moore, Ethological principles predict the neuropeptides co-opted to influence parenting, *Nature Communications,* 2017, 8, 14225. DOI: 10.1038/ncomms14225

CB Cunningham, K VanDenHeuvel, DB Khana, EC McKinney and AJ Moore, The role of neuropeptide F in a transition to parental care, *Biology Letters,* 2016, 12, 20160158.

NJ Royle, SH Alonzo and AJ Moore, Co-evolution, conflict and complexity: what have we learned about the evolution of parental care behaviours?, *Current Opinion in Behavioral Sciences,* 2016, 12, 30–36.

DJ Parker, CB Cunningham, CA Walling, CE Stamper, ML Head, EM Roy-Zokan, EC McKinney, MG Ritchie, AJ Moore, Transcriptomes of parents identify parenting strategies and sexual conflict in a subsocial beetle, *Nature Communications,* 2015, 6, 8449.

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