3 Clues to Where Sensory Consciousness is at Work

Geographical learning, or cognitive map-making, is the most widespread behaviour which seems to demand some degree of sensory consciousness. Without it, it's hard to see how the relationship between current surroundings and places now out of sight could be deduced, or how a goal could be chosen, and remembered during the journey. And mapmaking is a particularly valuable talent, so it seems reasonable to suppose that this is the context in which consciousness first appeared.

If the hypothesis is correct there should be a large number of species which are capable of making cognitive maps, but don't have the ability to apply sensory consciousness for other purposes. Such animals can be supposed to have some sort of awareness of where they are and where they are going; but they do not have to think, as it were, about eating, or their interactions with other animals. They perform those behaviours as automatically as we sneeze, or withdraw our hands from a hot surface, without needing to consider alternatives or make a decision. To put it another way, an animal whose consciousness is only concerned with a cognitive map may think about where it goes to eat, but not about what it eats. Its plan to make for a place where food is likely to be found can be supposed to involve a conscious sense of hunger, and perhaps a memory of past satiety in that place, but no conscious idea of a particular sort of food.

There should also be other species which apply sensory consciousness in a wider range of contexts. They may be supposed to think about a number of their activities; but the range of behaviours for which they can exercise prediction, planning and choice may still be narrower than is the case for us (even after allowing for the fact that they enjoy a narrower range of potential behaviours than we do). The logic of evolution indicates that our closer relatives should certainly use sensory consciousness quite extensively. And there is nothing to say that a broadly similar device could not have evolved in other, very distant branches of the animal kingdom. Indeed, it may well have done.

It’s often very hard to imagine that other mammals might not have conscious sensation and conscious intentions. The dog trotting down the road with a purposeful air so obviously seems to know where it’s going. Monkeys and squirrels, leaping daringly from branch to branch, can hardly be simply responding to stimuli in a pre-programmed manner, and if they had to perfect an inborn behaviour pattern by a conditioning process they would be very lucky to survive the education. A young cat preparing to jump on to a fence eyes the top of the fence, crouches a little deeper as if about to take off, pauses to study the distance again - no question but that it’s contemplating how to produce a powerful enough leap.

But these subjective impressions carry little weight in science. How can the possibility of other species’ consciousness be more objectively investigated? The question is less impenetrable than it might seem. It's certainly not difficult to deduce that a good many species have a very efficient grasp of the geography of their home territories.

The idea of the cognitive map is founded on the fact that rats go in for exploring just for the sake of it, and learn more geography when they do so than when they are distracted by the presence of food. Species which waste energy are unlikely to flourish, so it's safe to assume that if an animal spends a lot of time on locomotion and on investigatory behaviours, without showing any noticeable interest in obtaining food or other immediate rewards, then it's building or updating its cognitive map. Even if many species cannot be as conveniently confined in a maze as the rat, nor as conveniently observed, it's obvious that many of them go in for exploration. Domestic dogs and cats provide particularly convenient examples. They check out their neighbourhood regularly, obviously know their way around, and since they are generally more than adequately fed at home they cannot be prompted by a need for food or drink (though they may not turn it down if they find it).

It also seems appropriate to attribute mapping ability to any species which defends a territory of any size - a territory, that is, which significantly exceeds the range of the species’ sensory systems.

Territorial animals make their way around their fiefdoms in a confident, purposeful and efficient manner, and they clearly remember where the boundaries are, the line beyond which a neighbour becomes an intruder. In some cases the boundaries are also marked out on the ground, by labelling convenient features with urine or faeces, or with scent from a special gland. Such odour-marking may perhaps serve as a useful aid to the animal's own memory, as well as a notice to potential trespassers. But the animal needs to have a pretty good idea of how to find its way around its boundary markers if they are to fulfil their function properly.

There are also other lines of evidence. In a good many mammalian species mothers leave the infant young behind in some sort of shelter while they go off looking for food, roaming far afield in the process. This would be an impracticable proceeding without an efficient and reliable means of finding the way back. Moreover the parent often travels a fair distance in a meandering fashion, zigzagging here and there, and then makes her way home by the most direct route available. Such skilful navigation certainly implies the possession of an efficient cognitive map.

The same argument suggests that birds must be equally well equipped. Birds too have to look after their offspring, and are absolutely obliged to deposit their eggs somewhere. It's notable that in some species parents can identify their own nest amidst a crowded colony of thousands, but may not recognise their own chick if it strays outside the nest, which suggests that they are much better at learning detailed topography than they are at learning to distinguish individual chicks. More amenable to experimental investigation is the fact that some bird species go in for hoarding food against hard times, and are pretty good at remembering where they put it. Research with a seed-hoarding corvid called Clark's nutcracker indicates that it uses a spatial pattern of landmarks to remember where its stores are - thus satisfying the definition of a true cognitive map. It's arguable, moreover, that a fair degree of mapping talent must have developed by the time avian ancestors took to the air, for flying seems an impractical proposition without an efficient means of aiming towards suitable places for coming down again.

But there are grounds for tracing cognitive mapping ability much further back than this. Several species of reptile demonstrably share the gift. Crocodiles remember where they laid their eggs and return to care for the hatchlings, and some species at least use the same nesting site every year. Some species of snake regularly find their way back to communal hibernating sites. Turtles, confronted with the cross-shaped maze experiment, use surrounding landmarks to find their way to the food just as rats do. A similar ability has been found in goldfish.

It seems likely that the fish which first ventured out of water and gave rise to tetrapods were endowed with at least some mapping ability before they went any distance on land, since they must have needed, like many modern amphibians, to be able to find their way back quite regularly. And a knowledge of the terrain would certainly be a valuable asset for any fish frequenting the shallows at the edge of the ocean, or any other creature living among rocks and dangerous currents.

It's tempting, in fact, to suggest that mapping ability began to develop quite early in vertebrate evolution, and may have been one of the factors that contributed to the success of one particular ancestor rather than another. The useful talent may have evolved more than once, for it's found in at least one other phylum. Some species of octopus, it's been discovered, establish temporary dens and can return to them after extensive foraging expeditions.

Other forms of exploration

For a terrestial species which moves about with any degree of speed, and especially one with a raised centre of gravity, knowledge of geography is not in itself sufficient. It's also important to know something about the possibly varied nature of the ground underfoot and the solidness or otherwise of the objects that make up the environment. What sort of ground provides a firm footing, and what sort of visual stimulation indicates stickiness that will slow down a running animal, or crumbliness that will slide away under impact? What sort of vegetation will bend and allow an animal to push a way through, what is an impenetrable and perhaps prickly barrier? What sort of visual stimulation presages a surface that will hurt if you come up against it too hard? These are things it's valuable to know when a route is being chosen, or a journey planned. They are particularly necessary for prey animals fleeing a predator, and for the pursuing predator.

For species which can travel fast, then, it's worth acquiring a map indicating more than landmarks and profitable places to visit. In fact it's probably only worth evolving the means of rapid locomotion, or evolving beyond a fairly modest size, if there's already a capacity for learning about the nature of the local terrain, so that reasonably reliable decisions can be made about where to put the feet. In many mammalian species close investigation of the immediate surroundings begins at an early age, while the animal is still under mother's protection. Careful prodding, with nose, whiskers and paws, educates the youngster about tactile values. When it grows old enough to leave mother, to explore more widely and form its own cognitive map, it will have some idea about what bits of terrain to mark on its map as best avoided.

For primates which climb high into the trees and are heavy enough to suffer severe damage if they fall to the ground this sort of knowledge is particularly important. They must have a very clear knowledge of what sort of branch or creeper will be strong enough to support them, and what is likely to give way under their weight. Not surprisingly, young primates show a great deal of curiosity about the world around them, and spend a lot of time investigating branches, twigs and creepers.

Whether young birds need to explore the nature of their surroundings too, or whether they can afford to learn the hard way, is a moot point. I've only once seen a bird make the mistake of trying to land on a twig that was totally inadequate for its weight, and that was a thrush which had been seriously distracted by hearing another thrush singing on his territory. When the twig swung down to the vertical and tipped him off he easily rescued himself with a quick flap of his wings. For many birds the occasional error of this sort perhaps isn't too expensive.

In some species, then, exploratory behaviour covers not only the general geographical lay-out of the environment but also some careful investigation of the tactile nature of its components. The knowledge thus gained underlies the predictions that allow a heavy animal to race across the ground at speed, or to leap through the trees. The guess is that conscious vision combines with conscious tactile feedback to create schemata which relate the visual stimulus-patterns presented by objects to their tactile quality.

To recapitulate the general theory behind the argument: where behaviour is determined wholly by the nature of the wiring from sensory receptors to motor neurons there is nothing to learn. Where the genetically preprogrammed responses can be modified by conditioned learning animals learn by chance, in the process of going about their normal business, but have nothing to gain by taking the risks involved in seeking for learning. But sophisticated sorts of learning, such as the construction of a cognitive map, can be supposed to involve a substantial investment in neuronal hardware, and species which have made this investment need to put a further investment of time and energy into acquiring the knowledge that will make it useful. Consequently the talent must come accompanied by a drive to use it, which ensures that it earns its keep. Without that, natural selection would not have permitted the costly machinery to evolve. Thus species which explore put a lot of effort into it. The animals not only learn their territory thoroughly to begin with, they go on checking it over regularly, which enables them to keep up with the changes that occur as a result of storm and flood, other animals' activities, or simply the passing seasons. And youngsters may invest quite a lot of time in tactile investigations, with paws or nose or whiskers, though the amount varies considerably from species to species.

This gives us a means of deducing in what other areas of activity a species might use knowledge gained through conscious sensation. We look for a parallel to exploratory behaviour - for activity apparently undertaken for its own sake, energy expended for no immediate reward, and learning that is achieved in the absence of detectable reinforcement. And that is a pretty good description of the sort of behaviour we call play. The type of play a species indulges in should give us a pretty good idea of what we want to know.

Play

Play occurs only in species with brains of a certain size (after adjusting for the fact that larger bodies need larger brains) and it seems to be especially provided for by a period of juvenility which intervenes between helpless infancy and competent adulthood. The length of this juvenile period correlates closely with brain size, reaching its peak in the great apes and of course in humans.

The implications of this were perceived over a century ago by Karl Groos, a psychologist: *Now we see that youth probably exists for the sake of play. Animals cannot be said to play because they are young and frolicsome, but rather they have a period of youth in order to play; for only by so doing can they supplement the insufficient hereditary endowment with individual experience.* For a large chunk of the twentieth century, though, play was carefully ignored. Difficult to define or to measure, it was classed as a hopelessly unscientific subject. Gradually, however, its importance came to be recognised. On the one hand it was realised that the more a species plays in youth, the more adaptive and creative the intelligence it shows in adulthood. On the other, deprivation experiments demonstrated that when individuals of species that normally play are denied the chance to do so, they grow up to be significantly abnormal and malfunctioning adults. By 1988 Arne Friemuth Petersen could report: *comparative psychologists now hold that a capacity for imaginative problem solving, as well as inventiveness, can only evolve in animal species whose young remain immature for a sufficiently long period.*

The most obvious sort of play is sheer physical activity, or motor play, involving rushing about, rough-and-tumble with playmates, and perhaps the use of twigs or other suitable objects as playthings. The knowledge a young animal acquires from such activity is vital to the business of planning and choosing actions - a knowledge of its own capabilities. The primate swinging through the tree-tops must not only know which branches will bear its weight, it also needs to know how far it can jump. The predator needs to know when to spring so as to have a good chance of bringing down a moving target. And the fleeing animal has a better chance of survival if it recognises which obstacles it can jump or scramble over and which to avoid. Just as we humans are well-advised to know our own agility before trying to jump across a stream or leap on to a moving bus, so the high-living primate or the fleeing prey must avoid trying something beyond its capacity. Motor play is the means by which a youngster discovers just what it can do, and just what choice of actions is open to it.

The learning is a little complicated because the animal begins its experimentation before it is fully grown. As it gets bigger and stronger its capabilities increase and it can achieve more ambitious feats, so its ideas of its own physical potential must gradually be adapted. The youngster needs to play pretty regularly simply to keep up with its expanding size and power. Once it's fully grown, however, it can afford to give up motor play, and most species do.

Most primates have extended childhoods - several years in the case of the great apes - and devote a good deal of time to play. A period of juvenility with time for a significant amount of play is also common among mammalian predators. The knowledge thus gained is part of the essential underpinning for the tactics and strategy that will be demonstrated by the adult hunters. And if carnivores spend quite a bit of their youth trying out the physical skills they will need in hunting, young herbivorous mammals likewise spend time (though not so much) practising the skills they will need to escape, and acquiring the knowledge that may enable them to take the best route when chased. In some species, meanwhile, not only running and chasing but all the movements in the repertoire may be tried out in play, including those that will later be employed in mating and in male competition for females.

Play has been observed in numerous mammalian species, including some that might seem unlikely gambollers, such as hippopotami and tapirs. There are even reports of it in the platypus. The large-brained cetaceans, meanwhile, go in for a great deal of it, and may (like apes) sometimes continue to play in adulthood. It's not so common among birds as in mammals, but it's found in some of the larger, longer-lived species, such as crows, parrots and gulls, and something that seems to qualify as play has been observed in one or two reptiles.

We humans are obviously prime examples of adaptable motor ability that is perfected through experimentation. Introspection indicates that the knowledge gained is phrased in terms of a memory of physical sensation, which serves to measure the amount of effort used in a task, and allows us to estimate the amount which will be required for a similar task. We develop what might be called motor schemata, derived from our conscious sensations of muscle contractions and extensions, and of bending joints. Other species which indulge in motor play can be supposed to hold the knowledge which allows them to plan and choose their actions in the same currency. An animal contemplating a jump surely thinks about the effort required, as we do, in terms of muscular sensation. Where a species indulges in motor play it's fair to deduce that the information reported by internal senses such as muscle stretch receptors has been promoted to consciousness.

The other vital thing that infants learn when they play is how to use feedback from other senses. For us and most other species the most important form of feedback about the results of our actions is visual. Our conscious visual perception of an object allows us to choose to reach for it. If we fail to make contact it's the conscious visual experience that reveals by how much we have failed, and how we have to adjust the movement when we reach again. Without some such feedback there could be no learning from failure - which means no learning.

The theory, then, is that visual consciousness was used first only for mapbuilding. I suspect it was linked to conscious feedback about some longlasting effect such as the state of fullness in the stomach, or perhaps internal temperature, something which could readily be correlated with the ongoing sensory input from the environment. It found new applications when additional forms of sensory information which could provide useful feedback were linked to it. A conscious sense of touch meant that it was possible to learn about the tactile properties of different parts of the visual environment, and use the knowledge for planning. When information about the position of the body and the deployment of the muscles was promoted into consciousness it became possible to evolve a more flexible musculature and learn how to use it, instead of depending on a preprogrammed repertoire of movements. A significant aspect of these developments was that vision itself became a feedback sense.

The more a mammalian species gambols in youth, the less perfect the repertoire of movements with which it is born, and the more clumsily they are performed. In some species only the essential business of finding the nipple and sucking is done efficiently, and even that improves with practice. Some of the earliest efforts at limb deployment may be so unco-ordinated, so experimental, that they can't be said to qualify as play, though they obviously constitute the first part of the learning process, the earliest explorations of motor possibilities. The need to practice and develop motor skills correlates with the possession of complicated musculatures, which require complex controls, and can be adapted to cope with varying circumstances. Species equipped with simpler muscular arrangements and purely hardwired control systems can be capable of impressive feats - catching fast-moving insects, for example. But these innate behaviours are stereotyped and non-adaptable. In the species which play, individual animals tend to develop their own distinctive style of movement.

Object Play

For species with some manipulative ability suitable objects often become playthings. Young carnivores jump at falling leaves, and roll small stones about with their paws. Dolphins dart after strands of seaweed, and try tennis strokes with their beaks. Some birds play not entirely dissimilar games with falling feathers. But it is among primate species, of course, that the scope for object play is greatest. It is doubtless from such play that the knowledge is gained which makes possible the use of objects as tools, and among the larger-brained species the invention and production of purpose-made tools.

No-one has yet had the luck to observe the invention of a new tool by a primate in the wild. Quite a few suggestive experiments have been done, however, with apes and monkeys kept in varying degrees of captivity. Back in the thirties Wolfgang Kohler spent many years studying a group of chimpanzees kept in a large enclosure, with individual cages for sleeping. In one experiment he left bananas outside the cages, out of reach, and gave the animals two sticks which could be fitted together and turned into a tool long enough to pull the bananas within reach. The result was not impressive. Only the dominant male of the group worked out the potential of the sticks and gained possession of the bananas.

Some years later another student of animal behaviour, Paul Schiller, decided to develop this experiment further and see what happened if the animals were allowed to play with the two-part stick before confronting the problem of using it to rake in food. In the first part of the experiment nineteen of the twenty adult chimpanzees who were given the sticks to investigate discovered how to fit them together within fifteen minutes, and the majority of them did it almost straightaway. When there was a banana to be hooked into the cage, however, only some of those chimps who had so readily fitted the sticks together earlier thought of doing it again. Those that did, moreover, took far longer to get around to joining the sticks together in the presence of the banana than they had when there was no reward in sight. The animals experimented with the potential tool components far more creatively, Schiller concluded, when their attention was fully concentrated on them and there was no material reinforcement to distract them.

This precisely parallels, of course, the experiment in which rats explored a foodless maze more effectively than one which offered them a material reward. Once again, the conclusion seems to be that this more sophisticated sort of learning is done for its own sake. It doesn't require material incentives, so it must be rewarding in itself. But a concept must be firmly established by much practice if it is to come readily to mind when it is needed, at a time when the attention is centred elsewhere.

Repetitive manipulative play in youth offers a perfect opportunity for developing such concepts. Play is an activity only undertaken when an individual is well fed, and not particularly interested in obtaining more food, which makes it possible to use a bit of food as part of the game. It becomes a plaything rather than a distraction. These are the sort of circumstances under which technological innovations for food-getting are most likely to arise. The most likely innovators, therefore, are older juveniles, who have developed good muscular control but are still free of adult responsibilities and thus have leisure and energy to spare.

This certainly seems to have been the case for one famous bit of innovation, among a colony of Japanese macaques on the island of Koshima. This group has been under continuous study for over fifty years now. Originally the monkeys inhabited a heavily wooded and mountainous terrain, so in order to tempt the monkeys to an area where they could more easily be observed the primatologists took to scattering wheat in a sandy clearing by the sea. It was a juvenile who discovered, almost certainly in the course of play, that if she scattered the wheat on water it would float, while the sand was washed off and sank. The habit of washing the wheat in this way was copied by her contemporaries, and by younger monkeys, and became established in the culture of the group.

Later on the scientists provided sweet potatoes too, and the same monkey initiated the practice of washing the dirt off them in the brook, or in the sea. The practice has continued, even though the sweet potatoes that are supplied nowadays have already been washed. Since the washing is now always done in the sea the experimenters speculate that perhaps the monkeys appreciate a salty flavour. The habit of venturing into the sea is also something that was initiated by juveniles - the original adults refused even to get their feet wet. But as the colony grew, and artificial provisioning was reduced to avoid the danger of the island becoming seriously overcrowded, the monkeys took to catching fish for food. (The habit largely died out again a few years later, when the population pressure reduced).

In the Jigokendain Monkey Park, elsewhere in Japan, macaques also live under fairly natural conditions. Here primatologists have been able to study how good they are at developing tool use when given a little prompting. They put a piece of apple in a transparent tube, and left a hooked stick touching the apple. When half a dozen monkeys had learnt to pull the apple out they left the stick further from the apple, then outside the tube, then yet further away. Next they tried leaving assorted sticks around, so that the monkey had to choose an appropriate one, and finally the monkeys were left to find natural sticks. Only a couple of individuals mastered the most demanding of these tasks, but one of them, called Tokei, added her own variations. On five occasions she was observed bringing a long stick to the pipe and biting it to a suitable length. And once she pulled up a shrub, plucked off the leaves, bit off the root, and used that.

Then, when no stick was available, Tokei began throwing a stone so that it pushed the apple to the other end of the pipe, carefully selecting an appropriate size. After a long interval two other monkeys copied this technique, and later yet a third. Other individuals did not attempt it, but sometimes stole the fruit before the stone-thrower could get it. Tokei, who held a high rank in the hierarchy, threw with less momentum when other monkeys were around, and could usually chase the would-be thief off before they could reach into the tube to gain the prize. One lower-ranking operator learnt not to try for the fruit in the presence of others, and the other often lost what it had worked for. When these stone-throwers became mothers an easier option emerged, since small infants could crawl into the pipe, and if they brought out the piece of apple the mother might take it off them. Only Tokei, however, actively pushed her infant into the pipe.

Clearly it’s significant that both these populations of macaques live in a more or less natural environment, where juveniles have plenty of opportunity for object play. The Jigokendian monkeys nevertheless took quite a while to work out how to get the food out of the transparent tube, and the Koshima troop had been eating grain for some time before the washing trick was thought of.

Since Schiller’s time, meanwhile, it has become apparent that chimpanzees in the wild make and use quite a variety of tools, mostly for obtaining valuable, protein-rich foods that would otherwise be inaccessible, but also for various other purposes. Gorillas prepare some of their food (such as nettles) in ways that require a similar sort of dexterity and intelligence. And orangutans, when carefully observed, turn out to have all sorts of tricks, and not only for obtaining otherwise inaccessible food. Leaves, for instance, are used for purposes ranging from cleaning the self or protecting the hands when picking up spiny fruit to making interesting noises. Branches may be used for swatting bees while the nest is raided for honey.

In captivity all the great apes are capable of using a wide variety of tools, if they grow up gaining suitable experience. Individuals brought up in close association with humans spontaneously copy quite a few of our tool-using activities, sometimes to quite remarkable effect. A few, given paints to play with, have happily taken to creating pictures, and some even give titles to the results, though to the human observer they generally seem to qualify as abstract rather than representational works.

Some species of monkey are also turning out to use tools in the wild. Guenons, for instance, like to take stones up into the trees to drop on noisy hornbills. The star players, however, are capuchins. Some have been filmed using a very effective hammer and anvil technique to crack nuts. The nuts are placed on a stone worn slightly hollow by much use and the monkey raises a heavy stone above its head before bringing it down on the nut with a remarkable amount of force. Other capuchin societies may bang a nut on wood, or use fragments of bone to get at the kernel. One individual was observed using a stone to shape a bit of bone to greater efficiency. The enthusiasm for object manipulation in this species was underlined when some captive capuchins were given lumps of clay to play with, and paint, feathers and leaves. Some of them spent up to half an hour moulding the clay into new shapes, and decorating the results.

Social Play

In social species one of the most noticeable characteristics of play is that it tends to be a social activity. Youngsters do play on their own, but usually only when no playmates are available. Human children may invent an imaginary playmate if no real ones are around. In other social mammals play is most commonly seen when two or more juveniles get together. It’s notable, furthermore, that the longest childhoods and the greatest amount of play are found in those species which live in groups. It can be deduced that play is important in developing social as well as physical and cognitive skills.

This conclusion was substantiated by Harry Harlow, who arranged for captive rhesus monkeys to grow up under various circumstances of social deprivation. He found that a monkey brought up with only its mother for company, and allowed no opportunity to interact with other young monkeys, fared very badly when, as an adult, it was finally introduced into a group. Such socially deprived individuals had no idea how to cope with their companions, looked miserable, and were sexual failures. Youngsters separated from their mothers but allowed regular sessions in the company of other young monkeys also showed serious handicaps as a result of the deprivation, but their social life was not so severely affected as that of the play-deprived group.

For social mammals a fellow member of the same group is probably, as Nick Humphrey emphasised, the most demanding and challenging stimulus there is. It's an inconsistent stimulus-pattern, which tends to react differently in different moods and circumstances. Moreover, a social lifestyle requires a delicate balancing act between protecting one’s own interests and maintaining the viability of the group. Social life, mammalian style, is probably only possible because a good deal of youth is spent studying for it. This is especially true of the complex social life practised by apes and monkeys.

Play also functions, it's been suggested, to promote social bonding. The group that plays together stays together, as Robert Fagan put it. No doubt play can serve this function because it's a pleasurable activity, and so inspires pleasant feelings (mostly) towards the playfellows. By this means it helps to ensure that by the time the bonds that bind a youngster to its mother are loosened, the more flexible bonds that tie the individual to the whole group will have been forged.

It may be significant that peccaries, which live in groups and show an exceptional amount of co-operative behaviour over food-sharing, defence and nursing, are enthusiastically addicted to play. This is one of the few species where the adults play too. Each herd has a playground, an area about two metres in diameter where the regular activity wears away all the vegetation. The main bouts of play take place here, but brief bursts of a minute or two can happen almost anywhere in the course of the group's excursions.

The bonding process is conventionally regarded solely as a matter of establishing emotional ties, but it must also involve perceptual learning. A basic requirement for the success of a social unit is that the members should be able to recognise each other. This is a challenging task in many ways. The differences which distinguish individuals of the same species are quite small. In addition, visual, aural and olfactory characteristics can all undergo gradual modification as the individual grows and ages. The urge to play prompts youngsters to pay close attention to their fellows, on a regular basis, and probably helps in the learning of this particularly difficult perceptual task, so that it can be performed with ease.

In social mammals it's been demonstrated that group members can recognise each other not just as co-members but as individual characters with distinctive behaviour patterns. Play clearly provides much of the knowledge of character on which chimpanzee politics is founded, and the playful interactions of juvenile social carnivores must greatly facilitate co-operative hunting in adulthood. Thus the time a species spends in play correlates not only with the sophistication of its motor activity but also with the degree of subtlety in its social arrangements.

A feature of social play is that there is a good deal of unforced role-swapping. One individual chases another, and then, without any ado, the chaser willingly becomes the chased. This experience of role-playing must be a good grounding for the changing nature of social life, where the same individual may move through several roles. A lively juvenile playmate may perhaps grow into a powerful male, work his way up to be leader of the pack, and then be replaced and become an unimportant has-been. Some individuals may be friends most of the time but competitors occasionally. The role-swapping of play prepares the juvenile mammal for the fact that social relationships are not inherently fixed.

It hardly needs saying that the play of human childhood involves a great deal of more complex role-playing - mummies and daddies, doctors and nurses, cowboys and Indians. These games seem to provide a means of beginning to understand the elaborate roles of modern human adulthood. Perhaps there is something of this in the play of other species too. Maybe young ungulates benefit from learning something of what it feels like to be chased, under circumstances where the physical sensation is not overlaid and dwarfed by fear. Certainly young female chimpanzees like acting a mother role, and are often eager to take over the care of younger siblings. This obviously constitutes useful practice, preparing them for future motherhood, but it seems quite possible that they are inspired, much as young humans seem to be, by the desire to explore what it feels like to do the sort of thing that mother does.

In addition it may not be too fanciful to see, in the changing roles that a social animal plays and in the role-swapping of juvenile play, a possible parallel with the business of technological innovation. Social animals must get used to the idea that individuals play different social roles at different times, and sometimes switch roles quite suddenly. A mind that can cope with these re-assignments of status is perhaps prepared for the idea that a stone or a bit of twig might also change its role.

Certainly it seems that missing out on social play doesn't lead only to social handicap. Dorothy Einon found that rats which lack companions to play with when they are young show below-average intelligence as adults. They are extremely active, but excessively wary of novelties, and their performance on standard memory tests is below average. They are also very inflexible, taking much longer than a normal rat to discontinue or reverse a learned response. Einon concluded that play promotes versatility in adult behaviour, and improves an animal's ability to learn.

The definitive features of play have been noted by Robert Fagan. It consists of behaviour which is undertaken out of its normal context, and which does not lead to its natural consummatory conclusion. Young animals chase each other without any purpose other than chasing, fight without trying to do any damage, mount without copulation; and doll's tea-parties generally do not involve the actual consumption of food or drink. Play actions are often exaggerated in form, and undertaken with excessive energy. And the sequence may differ from the normal, functional performance, or may even include acts from different contexts.

Even without these guidelines we find it easy to recognise play in other species. It's made easy by the fact that the participants need to make their intentions plain. Confusion between play and more serious intentions could be expensive. It's especially important that an individual knows when it's being invited to a play fight, rather than challenged to a serious one. As the capacity for play has evolved, therefore, there has also evolved a signalling system which indicates *this is play.* And in the species which sometimes play as adults the signals are very well developed. A play-face, with mouth dropping open in something like a grin, has been well documented among various primates and carnivores. There is also, in quite a wide range of species, a sort of jump-and-crouch-and-pause-with-head-on-one-side which constitutes an invitation to play. We instinctively use, and recognise, fairly similar means of indicating playful intentions, so it's not too hard to read the messages expressed by fellow mammals.

Play and Adaptability

Play, then, goes with modifiable motor patterns, practical ingenuity, and demanding social lifestyles. In species which possess one or more of these characteristics there is a period of juvenility during which the necessary practice can be carried out, and the necessary ideas developed. Where there are complex sorts of learning to be done the process begins with playful experimentation in youth. In line with this, Konrad Lorenz noted that the species which go in for a lot of play are those which occupy varied types of habitat, and those which are not specialised in their diet but eat many types of food. Such species have larger brains than animals which are more set in their ways - the latter can reasonably be assumed to depend more heavily on innate behaviours.

It's now also widely accepted that the correlation that applies to species holds good for individuals too. Both among humans and apes, the most creative individuals tend to be found among those who remain most playful in adulthood, while playful females seem to make the most successful mothers, educating their young most effectively. The urge to explore and to play is also the urge to investigate, to mess around, to see what can be done with something, to develop fuller concepts - and this curiousity is what drives art, science and technology. (The connection between play and art was noted by Herbert Spencer, in his *Principles of Psychology*, published at the end of the nineteenth century.)

The link between the evolution of larger brains and the evolution of play behaviour is a two-way one. Play is something that happens when nothing more important is going on. Youngsters do not play when they are hungry, thirsty, tired or frightened. They play when all wants have been satisfied, and when mother is at hand to ensure that they are safe, or when they are within easy reach of the security of home. This often means that play occurs while mother is resting. But the immediate requirements of survival always have to come before the investment in education for the future. When times are hard - when food is scarce and a good deal of energy has to be devoted to finding it, or when there are many dangers about - then the time given to play is reduced, or there is no play at all. At such times the youngsters lack either one or both of the two essential ingredients, a surplus of energy and a sense of confidence.

However, it has been observed in both humans and rats that if the young are deprived for a relatively short time of the usual chances to play, and are then provided with a suitable opportunity to make up for it, they tend to do so, playing more exuberantly and for rather longer than usual before they tire of it. So the evidence suggests that there is a natural ration of play for each species, one that is perhaps dictated by the amount of energy that can be spared from the more basic requirements of life and of growing.

If the bigger-brained species are the ones which need to do the greatest quantity of this sort of learning they are also the ones which, thanks to that learning, are likely to get through the really important business of the day, the consumption of food, with time to spare - time in which the adults can laze around and the youngsters can play. And not only can they acquire an adequate ration of calories with time to spare, the youngsters get a sufficient surplus to allow for the exuberant expenditure of energy which play represents. Herbivores have to spend a great deal of time chomping if they are to obtain adequate nourishment, so play for them is largely confined to the period when a high input of calories is being obtained quickly and easily, by suckling.

The same consideration explains why primates in captivity, who do not have to travel and search for food, tend to be more inventive than those in the wild. They have almost unlimited time in which to investigate and play - if their environment provides adequate space, things to play with, and interaction with conspecifics.

The argument, then, is that play is the means by which an animal rehearses those behaviours for which it is equipped to be flexible and adaptable, the behaviours about which it learns to make predictions on which it can base choices and plans. These behaviours are the part of its life for which it needs conscious sensation.

A species which explores its surroundings, we can infer, enjoys some degree of consciousness in at least one distance sense - probably vision or olfaction, or more commonly both - for finding its way about. It may also be supposed to have some degree of consciousness in at least one feedback sense, which provides the means of marking useful places on the map. A species which investigates the tactile properties of its surroundings can be deduced to have conscious tactile sensation too, and the means of linking it to conscious visual sensation. A species which indulges in motor play must include in its conscious sensations the information provided by muscle-stretch detectors and joint-position detectors. And a species which lives in complex social groups regulates its interactions with other group members with the aid of conscious emotion. (Great apes, it may be concluded, have a conscious sensory and emotional experience which is broadly comparable with ours.)

This conclusion doesn't seem outrageous. It's certainly very hard to conceive of an animal without any conscious sensation indulging in play. A further argument is that play is generally not - at least not in the case of the initiator - an action triggered by an external stimulus, a response to an environmental cue. Nor is it an action set in train by an internal cue, such as hunger or thirst. The impetus for initiating any particular bit of play has to be an inspiration conjured out of the animal's brain. It implies the availability of some of the mechanisms that are necessary for making a plan.

Jerome Bruner, Alison Jolly and Kathy Sylva, in their preface to an excellent collection of papers on the subject of play, came to the same conclusion that Karl Groos had reached eighty years earlier: *play is the principal business of childhood.* It was the increasingly detailed observations of wild apes and monkeys, they suggested, which led to a realisation that the role of play during immaturity *seems to be more and more central as one moves up the living primate series from Old World monkeys through the Great Apes to Man - suggesting that in the evolution of primates, marked by an increase in the number of years of immaturity, the selection of a capacity for play during those years may have been crucial.* In other words the evolution of increasingly large brains among primates had been accompanied not only by an increase in the number of years of immaturity, but also by natural selection operating on a capacity for play.

Conditioned learning, with heavy-handed logic, links a certain sort of feedback to the action evoked by a certain sort of sensory stimulus-pattern, via channels which are genetically ordained. Several neuroscientists have proposed that sensory consciousness functions as a means of bringing a wider variety of information together. (Just how many strands of information can be woven together in the machinery of consciousness must vary from species to species.) Discovering the correlations between more varied inputs involves experimentation, while establishing the reliability of the correlations and fixing a record of them requires repetition of the experimental behaviour. This is what play achieves.

Exploration and play seem to offer a useful, though not necessarily comprehensive guide to where sensory consciousness is at work. Can we also guess where it is absent? I think there is one indicator available, at least. Genetically determined responses to genetically determined stimulus-patterns are often insensitive to the size of the stimulus - as they can afford to be if, in the habitat which the species normally occupies, there is no scope for ambiguity and confusion. In the streams in which British sticklebacks evolved, for instance, any moving patch of red was likely to be another male stickleback, and there was no need to allow for the possibility of a passing Post Office van. Similarly, the mating system of some species of frog involves all the males gathering round a pond at mating time and croaking their loudest. When a female arrives she is attracted to the loudest vocalisation, which means that she is likely to choose a strong and fit partner. If there is nothing else around that sounds quite like the mating call the system by which the female registers the signal does not need to incorporate any control for scale.

A system like this does, however, leave scope for misapplication. Cuckoos can get other species to bring up their young because the small birds in whose nests they deposit an egg have hardwired responses to eggs and nestlings which include no firm specifications as to size, so they continue to feed the alien even when it grows to be bigger than them. Indeed, with genetically determined systems an oversized stimulus may evoke a particularly strong response. Once, on a beach in Goa, my companion playfully started chasing a tiny crab, about the size of my fingernail. It retreated at first, but then started to defend its territory and became extremely belligerent, waving its fighting claw in the air, making rushes towards our feet, and then standing on tip-toe for greater impressiveness and waving again, until we retreated. This potentially rather dangerous lack of a sense of proportion can safely be assumed, I think, to go with a lack of sensory consciousness in respect of the relevant behaviour.

Recapitulation

The ability to build a cognitive map is extremely valuable, and seems to be pretty widespread among vertebrates, and it's hard to imagine how mapping could be done without some degree of sensory consciousness.

We can guess, then, that animals which put energy into exploring for its own sake have at least some degree of sensory consciousness - probably visual and/or olfactory consciousness, accompanied by a conscious feedback sense.

Some species explore aspects of the nature of their environment, as well as its lay-out, which implies a conscious tactile sense.

Many larger-brained vertebrates grow slowly into adulthood, and pass through a period of juvenility during which they devote time to play. Motor play is common, providing a means by which an animal finds out what it can do, thereby putting itself in a position to choose and plan its actions.

It's also a means by which a repertoire of quite rough-hewn movements is transformed into an extensive range of finely controlled ones. Motor play must entail a conscious sense of the feel of movement, and a conscious feedback sense to indicate when an action has fulfilled the plan, or, most importantly, how it failed.

Suitably endowed species also indulge in play with objects.

In social species the young play together and learn how to live together.

The length of the period of juvenility, the amount of time devoted to play, the size of the brain and the adaptability of the species are all correlated.

It seems reasonable to deduce that the sort of play that the young of a species goes in for provides a strong clue as to the areas in which sensory consciousness is present in that species.

On the other hand a tendency to respond to a drastically oversized stimulus suggests that sensory consciousness is not involved in guiding that type of action.