V for viability

It is not always for economy that birds fly in formation, says s anthanarayanan

THE iconic "V" formation of geese in flight has been found to be aerodynamically the exact way to minimise drag and optimise effort in long flights. But a detailed study of birds in flight, by James R Usherwood, Marinos Stavrou1, John C Lowell, Kyle Roskilly and Alan M Wilson at the Royal Veterinary College, London, shows that flying in groups is often costlier, in terms of effort, than flying alone and the reason that birds choose to fly in groups may be other gains of community living.

Just like pushing through a crowd in single file is easier than going three abreast, there is an advantage in flying behind another flying object. Any flying object is able to stay airborne because its forward motion generates *lift* that is equal to its weight and thus keeps it from falling to the ground. The angle of the object to generate this lift doesn't come free but it causes *drag*, which the object must overcome by effort, like burning fuel in the engine in the case of an aircraft or the flapping of wings, in the case of a bird. But if one is flying behind a leader, the drag is partially overcome by the leader's effort. There is also some advantage in getting "lift" from the vortices, or the upward movement of air caused by the leader. The followers can thus fly at a shallower angle and there is an overall economy of effort.

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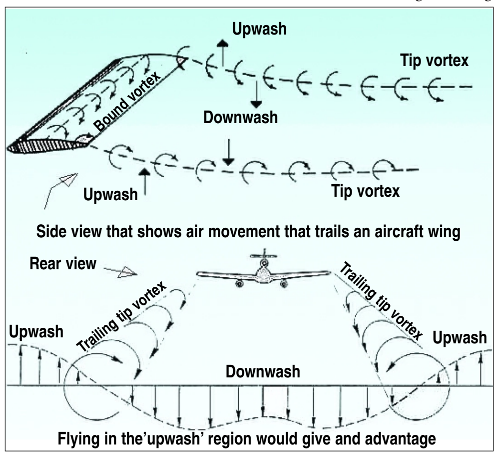
Fighter aircraft move in formation for awareness of mutual locations to be alert and stay in training, to enable planned manourvres and for mutual support and security. Fuel economy is not a consideration.



The best saving, in fact, is not directly behind the leader but slightly to the side, which gives rise to the **V** formation of geese in flight.

A study a few years ago monitored the heartbeat of pelicans in flight and showed that the heart rate was much slower when flying in the **V** formation. When a large number of birds is involved, the group can position itself to further tweak the mutual benefit and it has been shown that the effort saving can be as much as 70 per cent. As the leader birds would naturally tire faster than the followers, geese and other birds that fly long distances in formation have evolved to rotate the leader position, so that the group as a whole is able to cover the largest distance before needing to rest.

Flying in a cluster

The group at the Royal Veterinary College noted that the **V** formation, however, was limited to large birds on long, migratory flights, the more common flight mode being in groups of birds flying close together. Did such flight also yield aerodynamic advantage? The London group used state-of-the-art monitoring devices to study the internals of a flock of pigeons in flight and found that it was the contrary that was true!

The study was of 18 pigeons during seven bouts of voluntary, straight and circling flight around their home loft over a period of more than nine pigeon-hours of flight, 400 pigeon-km and over 243,000 flaps. Back-mounted Global Positioning System devices enabled pinpointing the position of each bird at every instant of flight and gyroscopic sensors recorded the acceleration and centrifugal forces the birds experienced. Wingbeat motions were monitored with a 300-Hz sensor and the study took into account the local wind conditions with the help of an anemometer mounted on a nearby rooftop.

The arrangement has yielded data in sufficient quantity and with the quality to allow, for the first time, mathematical and statistical analysis of the relationship of the flap frequency and body motions, as measures of effort expended, with airspeed, induced, climbing and accelerating power, and proximity to other pigeons. The data is sufficient to separately examine the effect of each factor, to be assessed for its cost in terms of effort, and the economy, if any, of different modes of flight.

The result of the study shows that in the case of pigeons flying locally around their roosting spot, there are a number of effects that do not arise in solitary flight. For instance, turning to the left or right, while flying in a group, calls for tilted or "banked" turns, like an aircraft, which increases the effective body weight, which then needs more lift to maintain flight. The observed higher flap frequency, which is mechanically less efficient, is needed to provide greater control, essential for flying in close proximity, particularly directly behind neighbours. This is a substantial additional cost of flying in a close cluster. The reasons of economy, which are celebrated in the case of geese and pelicans, are obviously not the motivators of group behaviour in the case of smaller birds that stay together over short distances.

Other benefits

At the same time, it is seen that even the classic long distance geese do not always stick to the mathematically ideal flying formation, for economy of effort alone. The V formation itself is not only for energy efficiency, it also provides the possibility of each bird being able to see the largest number of other birds, so the group stays together. In the case of smaller birds on shorter flights, the benefit of energy conservation is also not a major factor.

Even if energy saving is a goal, it may not be paramount, unlike on long flights, across stretches of water, for instance, where it is important that the group is capable of reaching the next place for resting and possibly feeding. The priorities may include mutual observation, collective guidance and navigation, enhanced security as a result of the greater numbers of individuals or of eyes, fitness display and assessment of group numbers. The coordinated bursts of flying in groups, by pigeons, may be for testing and maintaining fitness and their ability to move fast and accurately.

It is evident that there is more than one reason for the way behaviour and flight in birds have evolved in the animal kingdom.

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Secrets of migration

'scale model' tells on salmon, writes lewis smith

SCIENTISTS have discovered that the life history of a salmon is contained in its scales, just as the age of trees is betrayed by their rings. The finding is allowing researchers to unravel the centuries-old mystery of where Atlantic salmon disappear to when they leave the rivers they were born in and swim out to sea. By analysing chemical signatures trapped in the scales of fish caught in rivers, scientists can work out which part of the sea each one has been feeding in as it matures, before heading back inland to spawn. Such analysis could help conservationists protect dwindling stocks.

The research showed that salmon from Dorset fed as adults mainly off Iceland and the Faroe Islands, while those from the Tyne headed off to Norway. Differences were also found between age groups, with older and younger fish preferring different feeding grounds.

Researchers can tell where a salmon has fed by analysing its scales.

Researchers have been able to pinpoint these areas because as the fish mature their scales absorb carbon isotopes whose proportions vary according to which part of the sea the fish are feeding in.

Dr Kirsteen MacKenzie of the University of Southampton's National Oceanography Centre and lead author of the research, which was published in the journal *Scientific Reports*, said, "As every salmon contains a natural chemical tag, we can now see where fish from individual rivers go to feed in the Atlantic." She said the technique should be equally valid for determining where other fish and marine animals, such as turtles and seabirds, have been feeding.

Since the 1950s, about four million salmon have been tagged in an attempt to trace them but only 3,000 tags have ever been recovered.

The Independent, London

Forms and functions

Condensation of chromosomes is a mechanical process for converting a long and tenuous array of genes into a compact, manoeuvrable unit, says tapan kumar maitra

CONDENSATION of chromosomes during the mitotic and meiotic cell cycles — mainly through the acquisition of a coiled or folded structure — is commonly viewed as a mechanical process for converting a long and tenuous array of genes into a compact, maneuverable unit. However, a correlation exists between the degree of condensation and the functional activity of the chromosome; that is, an uncoiled state of the chromatin is a prerequisite to synthesis, whether this it is a replication or transcription.

Observation of nuclei reveals that the condensation of chromatin is variable. The chromomeres of meiotic chromosomes, including those of the lampbrush variety, bands of polytene chromosomes, knobs such as found in maize and the chromocentres of interphase nuclei (including the Barr body, or sex chromatin, of placental mammals) are, simultaneously, expressions of chromatin condensation and relative biochemical activity.

Condensation may involve parts of chromosomes, whole chromosomes, or entire haploid complements, as in certain coccids. From the point of view of function, therefore, the chromosome possesses a mechanism for the differential expression of gene action. This would assume that different ceils in the same organism inactivate, selectively, different transcribing elements through condensation, a point difficult to prove by visual observation of ordinary somatic cells, but readily observed in polytene and lampbrush chromosomes and one that is reasonable on the further assumption that not all the genome is active in all cells of the body.

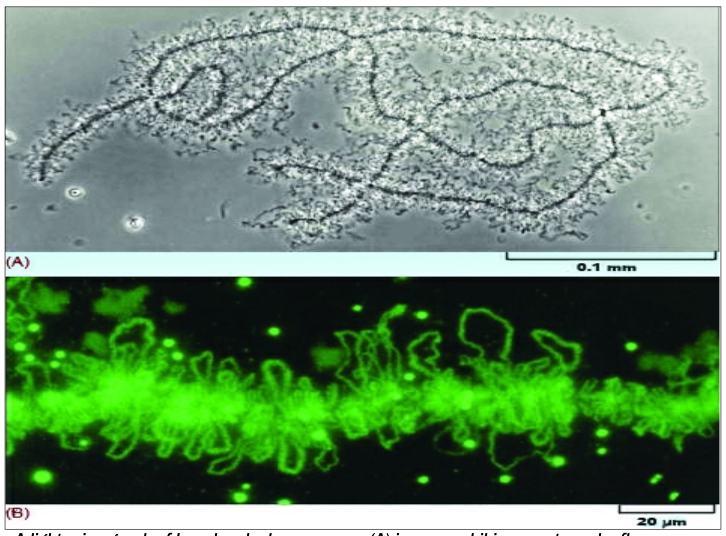
The fact that portions of chromosomes are differentially active during development has been examined most closely in the polytene chromosomes of dipteran species. The banded structure of the polytene chromosome permits the correlation of a gene with a given band. In addition, given bands undergo change that can be correlated with developmental progress, the change being expressed visibly as a puffing pattern. At each puff, messenger RNA is being actively produced, an indication that the gene or genes at these loci are functioning while other genes in regions of normal banding are presumed to be inactive. Two examples of the specificity of the puffing phenomenon may be mentioned.

Beermann has shown that wild-type individuals produce a secretion granule in the cells of the salivary gland and that these granules originate from a particular puff. A mutant form lacks the ability to produce the granule and it lacks the puffed region. Heterozygous individuals show a puff in only one of the two homologous chromosomes. The conclusion drawn from this evidence is that opening of the chromosomes through uncoiling, and as made visibly evident by puffing, is a necessary step for the synthetic activity of genes, presumably by exposing sequences of DNA for transcription by RNA polymerase. This is suggested by the general observation that at interphase in normal cells, major cellular synthesis is correlated with the chromosomes being in a dispersed state, whereas from prophase on only specialised and active centres such as the centromere and the nucleolar organiser are in a relatively uncoiled state. Differential coiling, at whatever time it occurs, may then be viewed as an expression of synthetic control of genie elements.

A number of other investigators have shown that in both larvae and in isolated salivary glands, the polytene chromosomes go through a specific and characteristic pattern of puffing and synthesis when exposed to the molting hormone ecdysone. Injection of this juvenile hormone, which is isolated from larvae of the Polyphemus moth into *Chironomus* larvae causes pupation to occur within a few days, even though the larvae would not ordinarily do so for a week or more. In addition, ecdysone evokes an immediate response in the salivary gland chromosomes — a particular region in a specific chromosome promptly puffs, to be followed in order by a whole series of puffs. The sequential pattern of puffing is the same as that occurring during the period of development when ecdysone would normally be present.

It is possible that ecdysone exercises its influence by inducing a localised uncoiling of the chromosome, this change being a prelude to specific RNA synthesis. Becker has recently suggested that the sequence of puffing is dependent upon the maintenance of chromosomal continuity, at least from puff to puff. When, for example, a translocation separates puffs that demonstrate a characteristic sequence in the intact chromosome, the pattern is disturbed.

Puffing in polytene chromosomes, like the loops of lampbrush chromosomes, is a reversible phenomenon; the puffs can form and then disappear. However, the turning off and on of genetic activity need not invariably be a reversible affair. This is suggested by the fact, as demonstrated first by Briggs and King, that nuclei of different cells in varying degrees of differentiation exhibit a variable capacity to sustain embryonic development. Thus, if the nucleus of a blastula cell is transplanted to an enucleated frog egg, the egg will proceed through development to adulthood without hindrance or abnormality.



A light micrograph of lampbrush chromosomes (A) in an amphibian oocyte and a fluorescence light micrograph (B) showing a portion of an amphibian lampbrush chromosome.

On the other hand, nuclei similarly transplanted but from cells at the gastrula stage are unable to promote development beyond the gastrula stage. Such nuclei appear to be irreversibly differentiated and it can be argued that certain genes necessary for early development have been permanently turned off. An equivalent and apparently permanent arrest of development can also be accomplished experimentally. Proteins derived from the nuclei of adult frog liver cells, and injected into a recently fertilised but still undivided frog egg, bring about cessation of development at the beginning of gastrulation. The embryos appear normal, but cell division ceases and the chromosomes are often grossly fragmented. Nuclei from these arrested embryos are irreversibly differentiated, for if transplanted again into enucleated eggs, they show a capability of promoting development only to the gastrula stage.

Serial transplantation over the course of several generations of embryos does not remove the inhibition; the chromosomal differentiation accompanying cellular differentiation affects the process of transcription at the same time that it is without effect on the process of replication.

These examples are manifestations of the control of gene action during ontogeny. Parallel changes in chromosome morphology are not always detectable with present techniques and degrees of resolution, but there is no question that the chromosome may reflect, in specific and characteristic ways, the functioning of the cistrons within it.

Sequence of events after injection of ecdysone into insect larvae

	Time after injection				
	0 min	*15-30 min*	*1-5 hr*	*7-10 hr*	*20-24 hr*
Experimental observation	—	**Puffing**	**RNA isolation mRNA isolation**	**Dopadecar-boxylase induction**	**Puparium formation**
Postulated celluar events	**Gene inactive**	**Gene active**	**mRNA formation**	**Protein (enzyme) synthesis**	**Cuticle tanning**

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