Simulating evolution

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A game to teach the principles of evolution using man-made artefacts

This is an exercise that I have successfully used over the last few years with a wide variety of different groups. It was originally developed by the Open University's Science Course Foundation Course Team for the S100 Course, Unit 21 'Unity and diversity', Study Guide.

The exact nature of the objects provided is not important, provided that they possess some material connection with each other. During the time that the students are sorting the items, the teacher may find it valuable to produce a 'fossil' object to add to the collection. This is produced by making an impression of an object in plasticine or, for a permanent exhibit, in plaster of Paris.

Aim

The principles determining the changes in structure which occur during the evolution of organisms can be applied to any collection of specimens. These can be arranged into 'evolutionary trees', showing the order in which changes in structure probably occurred. The same kind of analysis can be applied to a collection of man-made artefacts, pretending that each is an organism and then determining the probable course of evolution. The phenomena of divergence of closely related forms, convergence of distantly related forms, and parallel evolution can all be illustrated.

Theory

The four principles or generalizations are as follows:

1. Organisms that resemble each other in many ways are probably more closely related than are organisms that resemble each other only slightly—i.e. the greater the similarity in structure (the more features in common) the closer the probable relationship between two forms.
2. Evolution is usually the result of a gradual accumulation of small changes in structure (and function) but occasionally there are larger changes.
3. In general, simpler forms gave rise to more complex ones and smaller forms to larger ones but there can be exceptions.
4. Evolutionary processes do not go into reverse, but specialized structures can be lost.

Practice

Either Acquire one specimen of each of the objects shown in the figure (note that it is not essential that your objects should be exactly the size stated).

Or Cut out each of the pictures of the objects in the figure, keeping the letter with the picture. Use your cut-outs as though they were the actual objects.

Take your collection of objects and arrange them on a large piece of paper to form possible evolutionary series. Choose the smallest simplest form as the probable common ancestor for the group and then try to arrange the others as branches of a tree derived from this ancestor. You can record the trees you construct by using the letters given to the objects in the figure. Mark on your trees the forms showing divergence, convergence, or parallel developments.

You should find that some lines of evolution seem very obvious whereas other specimens are quite difficult to place. Some may fit in several positions.

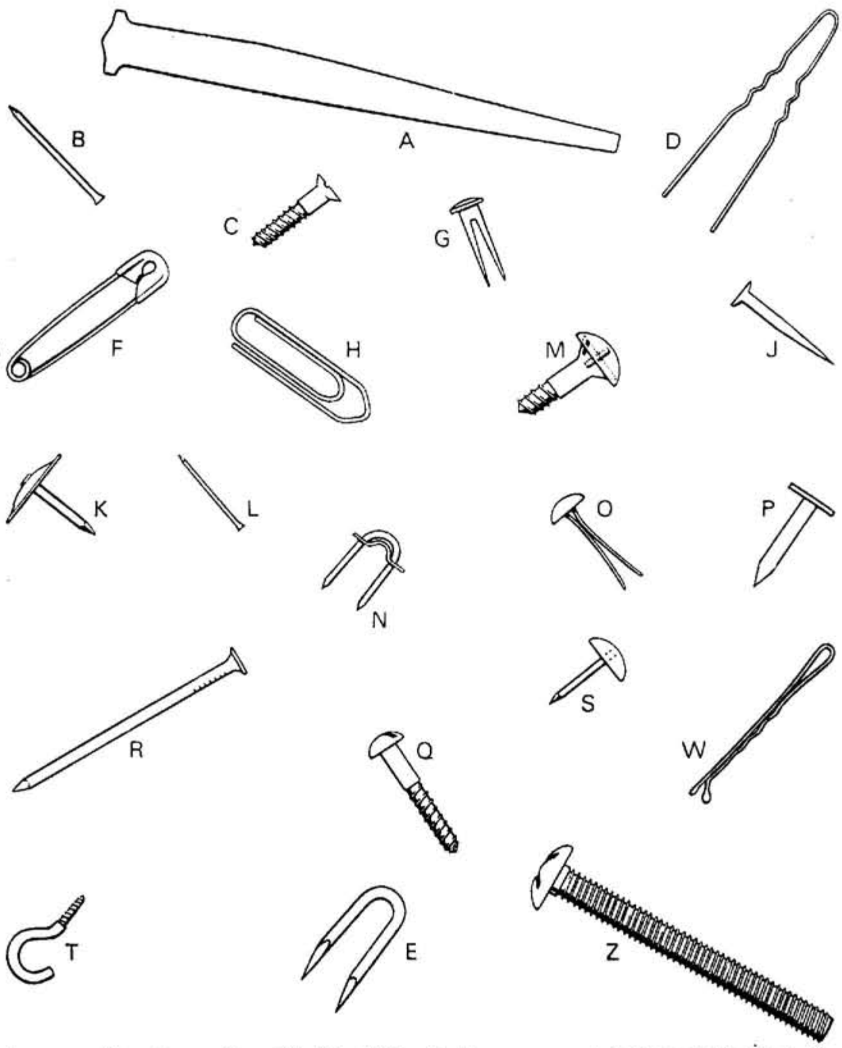
N.B. Although this is a wholly artificial situation, you are dealing with the same sort of problems as those faced by palaeontologists using specimens of fossils or entomologists using specimens of dead insects in museum cabinets.

Some solutions to the problems

Using the letters as in the figure, the common ancestor is probably L—a small simple form with a tiny head and simple shaft.

1. L→B→R is an obvious line showing increase in size.
2. L→J→A is a parallel line with a square shaft and larger head between L and J. L or B or J could have →C by increase in complexity of head and shaft. (L or B seem the more likely ancestors because J has a square shaft.)
3. C→Q→Z is a line showing increase in size, increase in complexity of head, and finally a change in the shaft. Probably C→T through change in head accompanied by slimming of the body.
4. L→S→K is a line showing increase in size and specialization of the heads. Probably S→P through increase in size but the material is different so it is possible that B or J→P in which case there would be a convergence between P and S/K.
5. Is G part of this evolutionary series? Either S or P could→G by thickening and subsequent splitting of the shaft. Probably G→O by a combination of elongation and slimming (a sort of eel-like series).
6. M presents an interesting problem: of its two parts, one, the base component, is clearly very close to C in structure; the other part, the top component, shows similarities to Z *but* the head is smooth not grooved; it also shows similarities to S *but* the shaft is threaded not smooth. Probably this is part of the radiation from C but it is clearly convergent to the S series. Are the two components two sexes (illustrating sexual dimorphism) or is M really a curious hybrid between descendants of C and S?

A 3-inch tack
B $\frac{3}{4}$-inch nail
C $\frac{3}{4}$-inch screw
D hairpin (2 inch long)
E staple (1 inch)
F safety pin ($1\frac{1}{2}$ inches)
G split rivet ($\frac{3}{4}$ inch)
H paper clip ($1\frac{1}{4}$ inch)
J 1-inch tack
K upholstery pin ($\frac{3}{4}$ inch)
L $\frac{1}{2}$-inch nail
M mirror screw ($\frac{3}{4}$ inch)
N insulated staple ($\frac{1}{2}$ inch)
O paper fastener ($\frac{3}{4}$ inch)
P paper fastener ($\frac{3}{4}$ inch)
Q round-headed screw (1 inch)
R 2-inch nail
S drawing pin ($\frac{1}{4}$ inch)
T Hook ($\frac{3}{4}$ inch)
W Kirby grip
Z bolt ($2\frac{1}{2}$ inch)

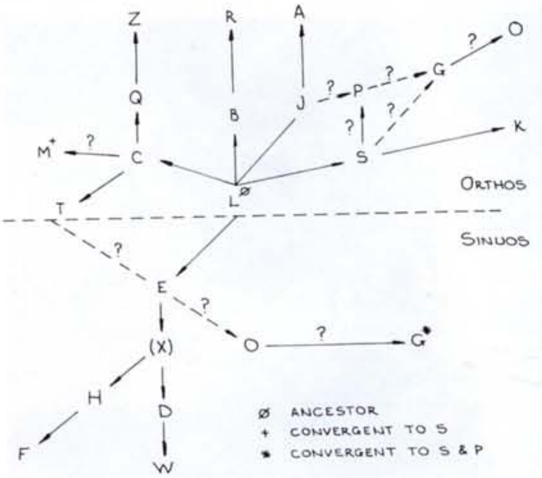


All the evolutionary series considered so far basically have a straight shaft and a single axis (exceptions are G and O where the shaft is double; T where the head is curved, is another highly divergent type). We could say that all these forms are members of a single order—'*Orthos*' (from the Greek for 'straight') or some similar name. The rest of the objects are bent in various ways—'*Sinuos*' (from the Latin for 'curve') or some similar name. Of these, the simplest form is probably E so this is likely to be nearest to the common ancestor.

7. Probably L→E by loss of its tiny head and bending of the shaft but it is just conceivable that T→E by loss of the screw thread and further bending of the head—it seems more likely that T is convergent to the series descended from E.
8. E→N by addition of the plastic insulation.
9. E→D by elongation and slimming of the two sides and appearance of waves in them.
10. D→W by further asymmetrical specialization of the two sides.
11. H and F look as though they are related, with H→F by addition of material to form a head. H might be derived from E by slimming and bending, possibly with a common ancestry with D; extra bends formed latter, thus E→X→(not represented in the collection)→D→W and X→H→F.
12. G and O have double shafts—could they be part of the 'Sinuo' series? O could be derived from E by slimming and development of the centre into a sort of head and then O could→G by strengthening and solidification. In this case, there would be strong convergence between G and S/P.

Thus the objects can be divided into two groups (orders) each of which can be derived from a common ancestor—L for the *Orthos* and E for the *Sinuos*—and it seems likely that the latter is derived from the former.

Within each 'order' there are several divergent lines. Series showing increases in size are common in the *Orthos* and these also show variety in development of the head and of the shaft both independently and together. The *Sinuos* show variety in the bending of the two shafts; they generally lack heads—this perhaps makes it more probable that G and O are *Orthos* and not *Sinuos*.



You may have thought out a quite different series of evolutionary lines—so long as you can justify them using the four general principles, then your series are just as credible as these. If the objects were living organisms, then there would be other possible lines of argument—such as studies of their cytochromes or of their embryology—which might support some of our hypotheses and suggest that others are wrong and so indicate more precisely the probable evolutionary series.

Pleural membranes: a simple model

D. R. B. Barrett

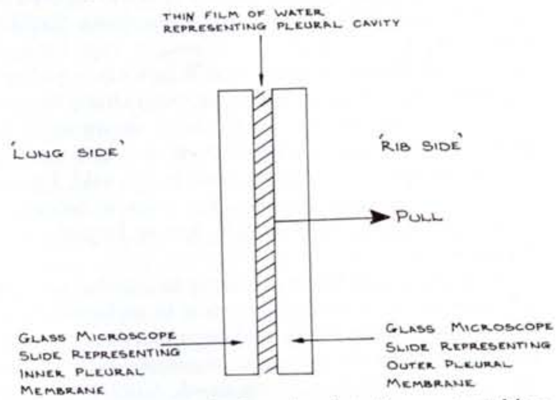
The use of models to teach human breathing is not uncommon. Indeed, the bell-jar model of the diaphragm and the intercostal muscle model are often described in textbooks. The model described below helps to explain the importance of the pleural membranes

When studying the mechanism of human breathing pupils learn that the inner and outer pleurae are separated by a thin film of fluid, sufficient only to lubricate the surfaces as they move over one another during breathing. They are taught that the 'space' between the pleurae is called the pleural cavity, and that as long as this cavity consists of an intact film of fluid the two pleurae cannot be separated except by considerable force. This is a vital property if breathing is to be successful but some pupils find it difficult to appreciate why.

A theoretical explanation may include the following points: Firstly, the contraction of the external intercostal muscles and the diaphragm causes the outer pleural membrane to be pulled away from the inner pleural membrane. This causes the pressure between the pleurae, which is already negative, to be further reduced. Secondly, this effectively creates a 'suction pull' on the inner pleural membrane which, as it is attached to the outer surface of the lung, causes the lungs to expand and stretches the elastic lung tissue. Finally, due to the increase in lung volume, the air pressure in the lungs becomes less than atmospheric air pressure with the result that air is sucked into them.

The model

A simple model to demonstrate the importance of the pleural membranes consists of two glass microscope slides. These can be issued to every pupil. One slide represents the inner pleural membrane and the other slide represents the outer pleural membrane. The surface of one slide is wetted and then both slides are pressed together; the fluid-filled space between the slides represents the pleural cavity (see figure).



Pupils can now be asked to simulate the events taking place during breathing by trying to pull the 'pleurae' apart. They will find this a difficult task to accomplish, thus demonstrating the manner in which the pleurae operate. Pupils should be warned of the danger of breaking a slide if undue force is applied.

Two glass microscope slides, lacking the fluid partition, could be pulled apart by pupils in order to demonstrate the effect of a pneumothorax.

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