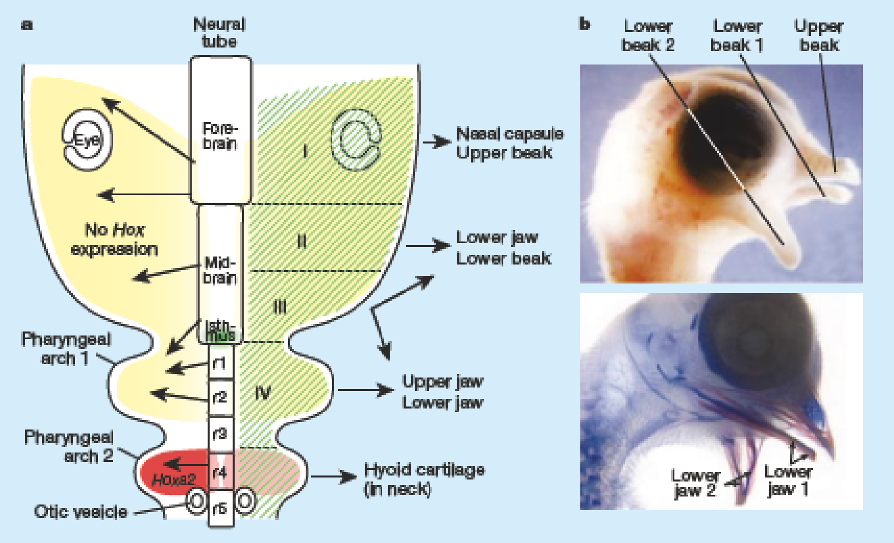

Figure 1 **Shaping the face. a, Flattened view of the back of a chick embryo. Left, during early development, neural crest cells migrate out of the neural tube and towards the forehead and nasal region (topmost bulge) and the pharyngeal arches. For simplicity, migration is shown only on the left, although it would occur on both sides in the embryo. Right, spatial relationships between the neural crest and the underlying pharyngeal endoderm, which is divided into regions I–IV. Trainor *et al.*[3] show that signals from the neural tube (such as from the isthmus) inform neural crest cells destined for the first pharyngeal arch about their position (for example, through repressing the *Hoxa2* gene). However, the cells' fate is not irreversibly set before migration. Then, signals from the underlying endoderm (green stripes) instruct the cells about the size, shape and orientation of the skeletal elements they will form, as Couly *et al.*[4] show. b, Grafting of an extra endodermal region II onto the original yields a fully duplicated lower beak and jaw, highlighting the importance of signals from the endoderm. Modified with permission from ref. 4. r, rhombomere.**

regional cues from the neural tube (such as FGF8 from the isthmus). Such signals must also be maintained in the arch, possibly to ensure that the cells segregate and migrate correctly. But the cells remain uncommitted until further instructed by the pharyngeal endoderm, each region of which contains information that guides the size, shape and orientation of parts of the facial skeleton. It will be important to identify the factors that control regionalization of the endoderm, and the exact signals that instruct the neural crest. During vertebrate evolution, the distribution or timing of such factors or signals may have been changed so as to mould different facial morphologies.

Some past results may need revisiting in light of the new work. For example, grafting rhombomeres 1 and 2 plus the isthmus more posteriorly in chick embryos[2,3] — leading to the inhibition of *Hoxa2* — and knocking out the *Hoxa2* gene in mice[5,8] resulted in jaw structures in the neck region. Given Couly *et al.*'s discovery[4] that the pharyngeal endoderm instructs neural crest development, this might mean that the endoderm of the second arch provides a signal like that from the first arch. But in that case it seems odd that posterior grafts of only the dorsal parts of rhombomeres 1 and 2, or of rhombomeres 1 and 2 without the isthmus, result in a largely normal second-arch morphology[3,10] even in the continued absence of *Hoxa2* in the neural crest cells[10].

A related puzzle is why *Hoxa2*-expressing neural crest cells, induced to migrate into the first arch, are unable to generate any skeletal elements at all[6,10]. A clue might come from an experiment in which jaw-to-neck transformations could be produced only when *Hoxa2* was artificially expressed in both the neural crest and the corresponding (first) arch[6,7]. Perhaps, to form the neck bones, *Hoxa2* is required not only in neural crest cells but also in other arch components. Tissue-specific knockouts of *Hoxa2* in mice, and further grafting experiments in chicks, may lead to the answers. ■

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Daedalus

Wave to the Sun

Photoelectric solar panels are stiff and brittle. Typically, they are optimized for high efficiency in spacecraft, where they unfold as rigid panels. Even earthbound photoelectric cells share this brittleness. Nature's photo-energetic devices — leaves — are flexible, and much better adapted to the atmospheric life. So DREADCO engineers are inventing a flexible photoelectric cell. Daedalus recalls Ovshinsky glass made to become semiconducting like silicon, the strong boron filaments created by decomposing boron hydride on thin hot wires, and the glass cloth woven from narrow flexible fibres. A narrow wire might be given a fine silicon coating by heating it in a silicon hydride gas. A metallized outer return lead would complete a filamentary photodiode, and the whole thing could be woven into some sort of textile.

DREADCO's 'Photofabric' would probably be inefficient. But as bunting, flags, sails, balloon fabric and so on, it would be well adapted to the atmosphere. Domestic users would love to 'fly the flag' at an energetic profit. Photofabric might even generate bulk electricity. Solar energy meets its main problems a few kilometres up, where clouds absorb sunlight. So Daedalus is inventing his 'kalloon', a combined kite and balloon, made of Photofabric and designed to get above this blocking layer.

Cloud-tops are very sharp when seen from the air. This suggests to Daedalus that the density of the atmosphere must fall at that height. His kalloon will nestle in this discontinuity. One old scheme proposes satellites carrying solar cells, to beam microwaves down through the cloud cover. Daedalus's kalloon will also deliver microwaves back to Earth. Cunningly, he will use its control lines as a spaced double Lecher line. Much lighter than any electrical conductor, this could steer energy very efficiently. A computer at the base of the system, like a tireless kite flier, would reel the lines in or out to keep the kalloon floating on the clouds and facing the moving Sun.

The kalloon might claim some government development money; it captures renewable resources. But Photofabric itself could benefit us all as a small-scale, universal power source. It would provide some of our own power, and thus reduce our power bills, for some folk perhaps to zero. It might change the whole assumption that power, consumed in small quantities, must be generated in big central stations.

David Jones