similarly after anchor ablation [4]. More generally, no trend is apparent in the placement of different species in the ternary plots of anchor cell ablation data across the genus. Of course, this may change as we learn more about *Caenorhabditis* biogeography and take into account the growing evidence for human influence on nematode distributions [12].

The third idea, and the one we favor, is that the involvement of Ras/EGF, Notch, and Wnt signaling in many other aspects of development, some of which are under selection, forces the vulval program to be constantly adjusted to accommodate this pleiotropy. Recent theoretical work suggests that such a combination of stabilizing and directional selection greatly speeds DSD [13]. We also find the idea appealing because of the great number of such pleiotropies involved. For example, in post-embryonic development alone, *lin-3*/Ras signaling is used in chemosensation, immune function, development of the excretory duct (which varies in position and development between *C. elegans* and *C. briggsae* [14]), neuroectoblast fate, axon guidance, male spicule development, and meiotic cell cycle progression [15]. Notch [16] and Wnt [17] signaling are similarly promiscuous.

What next? To address the canalization idea, the short lifespan and simple culture of *Caenorhabditis* suggests an experimental-evolution approach. In such a strategy, a genetic or environmental condition that challenges one or more signaling pathways is maintained for many generations, after which quantitative shifts in the response to anchor-cell ablation may occur. Given its relatively high genetic polymorphism [18], *C. remanei* may be the appropriate system for such a study. To investigate the pleiotropy idea, one could perform a similar experimental evolution scheme, with divergent environments specifically chosen to provide the required mix of stabilizing and directional selection. Alternatively, examination of genetic correlations between vulval development and other traits utilizing the same pathways could provide evidence for this dynamic. The recent emergence of a robust community of evolutionists studying *Caenorhabditis* [19] suggests that progress will be rapid.

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Object Recognition: Similar Visual Strategies of Birds and Mammals

Behavioral testing has revealed that pigeons may use the same visual information sources as humans to discriminate between three-dimensional shapes.

Kristina J. Nielsen[1]
and Gregor Rainer[2]

The lineages that eventually led to birds and primates evolved independently from a common ancestor which lived about 300 million years ago. Since that time, birds and primates have been shaped by different environmental pressures, as a consequence of which their brains show some similarities in their basic design, but also pronounced differences [1,2]. Vision is a key sense both for primates and birds, and both species use it for similar purposes, such as locating and identifying objects. Given that the two species have evolved independently, do they nonetheless solve visual tasks in the same way?

As they recently reported in *Current Biology*, Gibson *et al.* [3] tested pigeons and humans on a very taxing problem central to real-world vision. The number of two-dimensional projections that any three-dimensional object can produce on the retina is essentially unlimited, because even small changes in viewing angle result in different retinal projection patterns for the same object. Still, in most situations the different projections of a three-dimensional object are linked correctly to the original object. It has been suggested that the visual system achieves this remarkable feat by drawing information from the edges present in the two-dimensional object projections. This assumption is based on the observation that some edge properties, like the shape or the cotermination of edges, change very little as the three-dimensional object orientation is varied, in contrast to surface properties such as shading.

It has therefore been proposed that the visual system exploits these 'non-accidental' shape properties to recover the correct three-dimensional information from two-dimensional projection patterns (see [4] for example). In their new study, Gibson *et al*. [3] investigated whether non-accidental shape properties are indeed the most informative regions for observers discriminating between different shapes, and compared the importance of these regions between humans and pigeons. If these distant species are found to use a common visual strategy, it would be reasonable to assume that it might be the optimal solution for the task, rather than the result of some cultural constraint.

To determine the strategies used by human and pigeon observers, individuals were first trained to discriminate between four different shapes, generated by taking snapshots of four three-dimensional objects. Gibson *et al.* [3] then determined the shape regions on which observers rely to discriminate between the shapes (the informative shape regions). These regions are determined

Figure 1. A comparison of the visual discrimination strategies used by humans and pigeons.

Each column corresponds to one object. The upper row contains the data for pigeons, and the middle row the data for humans. Colored regions indicate the shape regions on which observers rely to perform a shape discrimination task. The results of different observers and their overlap are plotted in different colors (see inset in the upper part for a legend). The bottom row shows the parts of the shapes that contain edge coterminations (green shape regions). (Adapted from Gibson *et al.* [3].)
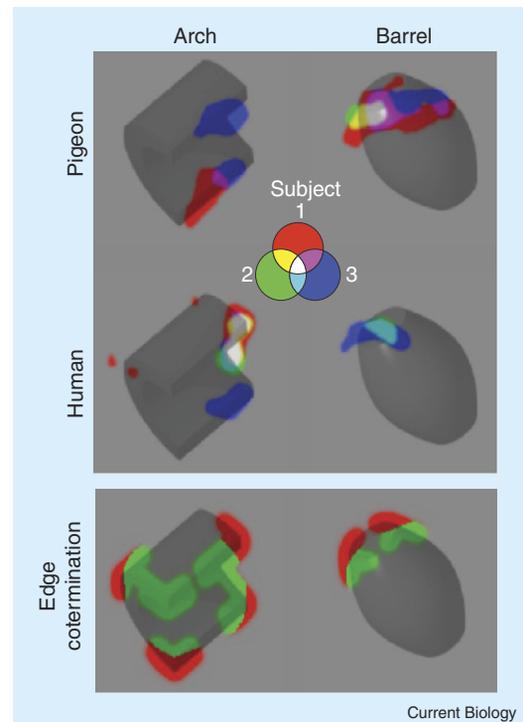
using a technique called 'Bubbles' [5], which was designed to explore the influence of any shape or image parameter of interest in an unbiased way by randomly sampling the complete parameter space for the selected parameter. To identify the informative shape regions, a spatial version of 'Bubbles' is used which relies on the presentation of the to-be-tested stimuli behind randomly constructed occluders. The occluders are generated as non-transparent surfaces, punctured by randomly placed round windows which expose the shape covered by the occluder. Informative shape regions are the stimulus regions whose occlusion systematically interacts with the observer's performance.

Knowing the informative regions of a shape makes it possible to determine whether they preferentially fall onto shape regions containing a particular kind of information. Gibson *et al.* [3] determined the colocalization of informative shape regions, with shape regions shown beforehand to contain edge information, edge cotermination, or prominent surface shading cues (only the first two are non-accidental shape properties). The results for pigeons and humans for two of the shapes

are illustrated in Figure 1. Across all shapes, it was found that pigeons, as well as humans, rely more strongly on cotermination information, and less strongly on edge and shading information. These results show that there is a universal tendency across species to use the same type of information, suggesting that cotermination information is indeed a very useful shape indicator at least for the discrimination task studied here. An interesting question for future studies is whether cotermination information is used not only to discriminate between different two-dimensional shapes, but also to confirm that it is indeed relevant for matching two-dimensional shapes to three-dimensional objects.

Pigeons have been tested on a large number of visual tasks, including tasks [6] very similar to those used by Gibson *et al.* [3]. The new study, and an earlier one which tested pigeons in a different task using 'Bubbles' [7], add important information to this literature, as they test humans and pigeons in exactly the same way using an unbiased approach. Animal strategies are often determined by experimenter-driven modifications of selected stimulus features.

While this approach can give important insights into the relevance of certain features, it has serious shortcomings because it depends on subjective assumptions about the relevance of different shape features. In contrast, 'Bubbles' is a method that samples a defined parameter space in an unbiased fashion. In most studies that have used 'Bubbles' so far, spatial aspects of the stimuli were sampled by showing randomly selected portions of each stimulus; however, 'Bubbles' can easily be extended to sample other parameters, such as spatial frequency channels [5], allowing future investigations into systematic effects of other stimulus parameters on perception.

Pigeons and humans are distantly related; while comparative studies between these species are interesting, as they can identify very general response mechanisms, comparative studies between humans and the much more closely related monkeys seem even more promising, particularly so as monkeys are the major animal model for human visual perception. Indeed, we have compared the performance of humans and rhesus monkeys on a discrimination task involving natural scenes using 'Bubbles' [8]: our work revealed some similarities, but also some interesting differences, in which regions of natural scenes were informative for monkeys and humans.

It seems that the strategies reported by Gibson et al. [3] are overall governed by what is optimal for the task at hand. Nonetheless, considerable inter-observer variability in strategies exists. This can be seen in Figure 1, which indicates the informative shape regions for each observer as well as their overlap. Interestingly, the inter-observer variability seems to be larger for pigeons than for humans, as we found in our comparison of rhesus monkeys and humans [8]. 'Bubbles' allows one to determine observer-specific strategies, making it possible to study how these unique strategies are reflected in the brain. Individual

differences among observers and among species can indeed have a strong impact on the underlying neural processing, as recent studies have shown [9,10].

In computer vision, the detection of three-dimensional objects remains an unsolved problem. Comparative studies between species, as well as detailed investigations into individual differences among observers in conjunction with monitoring of neural activity may prove useful for the further development and refinement of computational vision algorithms. The new study [3] highlights the importance of edge cotermination as a crucial factor in three-dimensional vision, in both birds and mammals. Whether the exploitation of this particular feature has been conserved from a common ancestor or has independently evolved in birds and mammals, it certainly represents a robust way of inferring three-dimensional structure from two-dimensional projections on the retina.

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Cell Migration: Catapulting Neurons from the Ventricular Zone?

In the developing vertebrate brain, newly born neurons migrate away from the proliferative zones. A new paper suggests that the initial phase of this migration may be propelled by the mechanical properties of the new neurons' processes rather than more conventional mechanisms of cell migration.

Jon Clarke

During development of the vertebrate brain, many neurons are born by asymmetrically fated progenitor divisions at the ventricular (inner) surface of the neuroepithelium. These neural precursors then migrate away from this proliferative zone towards the pial (outer) surface of the developing brain where they will mature and integrate into neuronal circuits. Two mechanisms of migration are thought to be important for this early journey in