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[*Editorial note:* Andrew Packard has reminded me that (among my no doubt countless other editorial misjudgements) I had declined to publish (when I was editor of *ASent's* predecessor and still thriving cousin, *BBS*) a paper that Andrew had submitted in 1987 ["The role of behaviour in evolution: A metaselection theory rooted in pattern recognition"] – a paper that went on to mature into two important published articles in Andrew's long and distinguished career (Packard & Cobb 2014; Packard & Delafield-Butt 2014). Not being a teuthologist, I can only plead that editors of peer-viewed journals are dependent on the expert judgment of their referees, so my guilt is shared! By way of penance, I have now accorded Andrew more space in his commentary than *ASent's* (or *BBS's*) default guidelines decree. – Stevan Harnad]

Keeping hold of Nurse

Commentary on [Mather](#) on *Octopus Mind*

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Abstract: Mather draws from a lifetime devoted to studying individual octopuses in the wild and in aquaria to combine a natural history account of their actions with an argument from design adopted from second-, often third-hand sources. The 'distributed' [decentralised] nervous system said to contrast with that of vertebrates – a premise largely accepted by Mather's commentators so far – does not reflect the original literature on motor control, nor the facts of comparative anatomy, functional morphology and morphogenesis. Ontogeny is absent. With the help of some old or little-known illustrations from my own participant-observer experimental investigations, I will try here to unpick threads of the pre-enlightenment embroidery shrouding the argument and will call into question the use of reductionist language.

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*“Read all the pedants’ screeds and strictures;
But don’t believe in anything
That can’t be told in coloured pictures”.*

G.K. Chesterton, *Lines Written in a Picture Book*

*“And always keep a hold of Nurse
For fear of finding something worse”.*

Hilaire Belloc, *Cautionary Tales*

One does not need to quote Kuhn to recognize that the paradigms ruling our particular field are being wilfully revised. Commenting usefully on this ambitious target article, already difficult for an ethologist of an upbringing different from that of Mather (2019), is compounded for the neurobiologist by the absence of a shared immersion in comparative anatomy. For handholds in this rollercoaster ride, I reach for the literature and for illustrations from my own past studies of the questions raised: (1) unified behaviour, (2) morphological basis, and (3) feelings.

Thank you to commentator Yoram Gutfreund (2019) for bringing in Niko Tinbergen; and to Luis Favela (2019) for expanding on the *Umwelt* [and *Umwelten*]: “*Umwelt* is quite appropriate when used in reference to organisms with a central nervous system, specifically, organisms that have a single subjective, conscious experience of the world.” (Choreographed by intersubjectivity, I would wish to add. For a mechanistic exposition of this in terms of 'pattern generation'/'pattern recognition' interplay, with octopus centre stage, see Packard 1988.) Thanks also to Sergio Pellis (2019) for recognising that comparison with the nervous system of vertebrates can be used to argue either way. Schnell & Vallortigara's (2019) attempt to reorient thinking is frontal; mine is from behind.

0. The unifying role of vision

I have used the classic approach/withdrawal language of Tinbergen and Lorenz to describe the behaviour of *Octopus vulgaris* (Packard 1963). This addresses Mather's conjecture that “octopuses may be guided by two motivational bases, exploration and fear.” Figures 1-3 illustrate how vertebrate-like learning and current experience affect the selection, deployment and intensity of the performance (some bilateral differences are just visible), but the postures themselves come from the rich repertoire of fixed action-patterns common to members of this species in the wild (Packard and Sanders 1969, 1971; Packard and Hochberg 1977b).

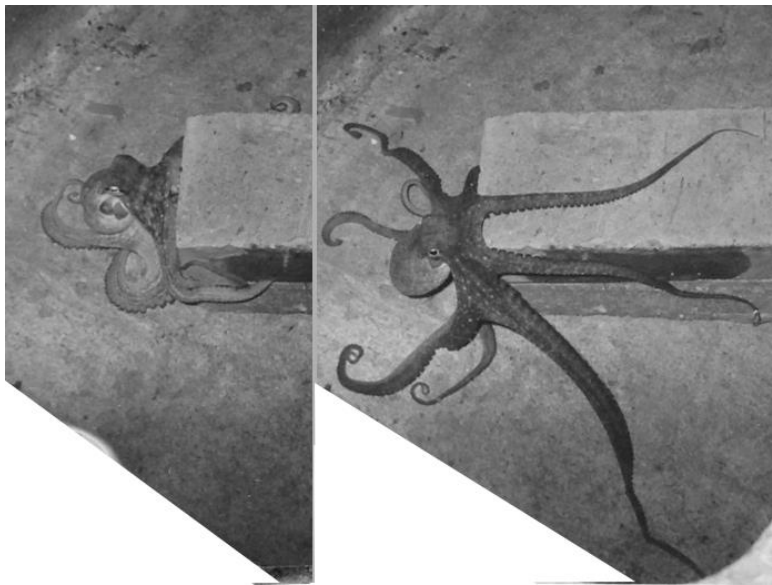


Figure 1. A pair of photographs of a common octopus in experimental tanks of the Naples Zoological Station captures its unitary response to my participant/observer action of switching off the overhead lights (see drawing in Packard 1972, figure 19).

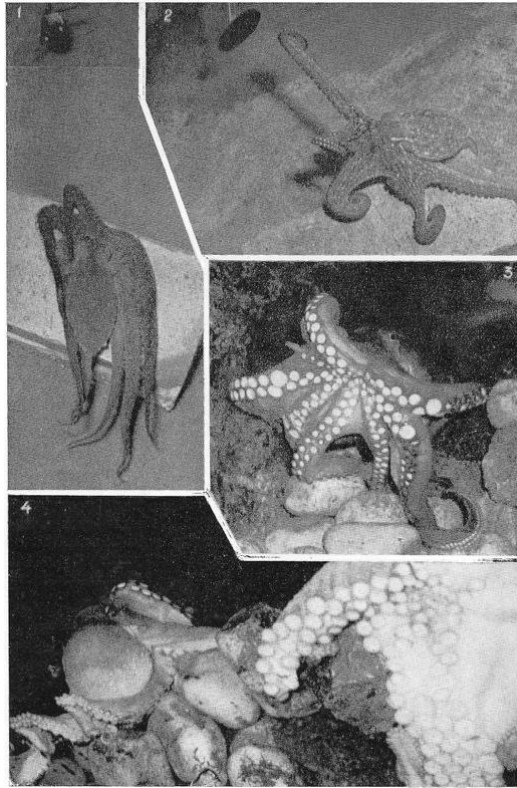


Figure 2. More sophisticated examples of 'voluntary' behaviors controlled by vision, including copulation, 'courtship' and emotional 'conflict' are seen in Plate 1 of Packard (1963).

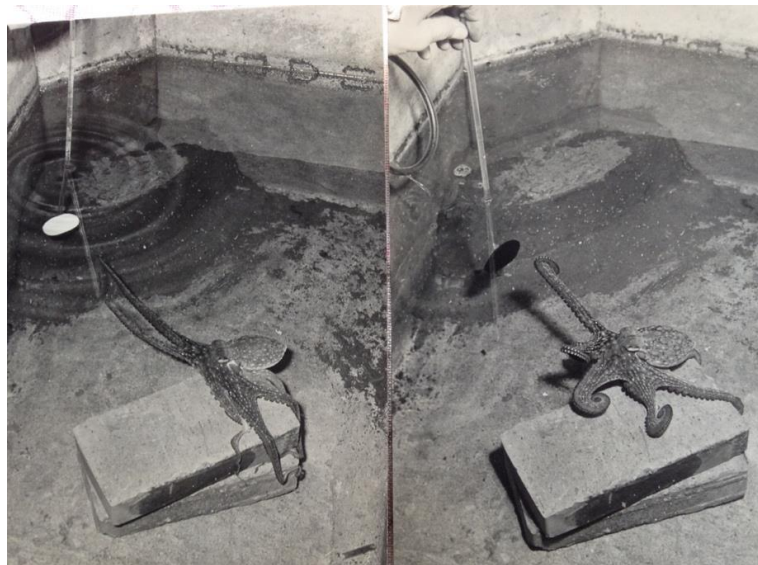


Figure 3. A second pair of photos (one of them figure 2 of the Monaco plate) captures the conflict between the two drives induced by my manipulation of targets associated with acquired positive and negative emotional signs: in this case, a cooperative, though captive, individual.

1. The argument from design

The 'argument from design' implicit in Mather's review of the recent 'arm movement' literature in octopuses replaces a morphogenetic logic with an anthropocentric (engineering) one. In view of the clear, simple, and ubiquitous evidence of the unifying role of vision in octopus behaviour, how did the idea gain currency that motor control and mind are *distributed* fundamentally differently in cephalopod animals compared to their counterparts in other animals? To gain an idea of the distribution and interplay of special sense organs and the various higher and lower centres of the nervous system delivering locomotion in our own species, it is sufficient to consult relevant chapters in textbooks for medical students, however ancient.

Both Jakob von Uexküll's 'subjective model of the world' *Umwelt*, and Young's (1964, 1978) encoded '*model*' were built from classical investigations in neuroanatomy, neurophysiology and experimental psychology. Von Uexküll (1894b) was one of the early workers on the octopus brain (*Eledone*), having already contributed to the understanding of peripheral mechanisms of chromatophore patterning (von Uexküll 1892; see Packard 1995b, Box 21.1) and of nerve impulse propagation (von Uexküll 1894a).

Figure 4 (below) contrasts Mather's position and my own. The two are destined to remain separate, however, if only because Mather's statement that "we do have enough information to evaluate how octopuses *might have a unity behind the diversity when organizing their world*" (italics added) has an Alice-in-Wonderland ring. The 'robotics' logic inherent in treating a soft body bearing eight flexible arms as a '*problem*' for the octopus (cf. introductory paragraphs of Hochner 2012; Levy & Hochner 2017; Crook & Walters 2014) – rather than just for the engineer/dance couple – stands upon its head an evolutionary description dating back to the enlightenment!

2. The devil in the details

Are "the dynamics of multiple simple and automatic elements" (Gutfreund 2019), sought by Hochner and colleagues in the arms of an octopus during oriented exploration of the substrate (bottom right in the open loop scheme of Figure 4), so different from the kind of "basic operation of the central pattern-generating circuitry" during 'fictive' locomotion adjustments delegated to the spinal cord in the decerebrate cat (McCrea 2004, cited by Mather)? This is painful to contemplate for an *Animal Sentience* community ethically concerned about those kinds of studies, yet no amount of observation in the wild can replace the findings of experimental neurophysiology.

Ostensibly holding onto Nurse, yet setting aside accepted nomenclature and relevant anatomical facts, the argument from design is supported by summaries of detailed histological counts of nerve cells in a common octopus specimen of unknown age and body weight (Young 1963) that has become an inflationary mantra for the octopus, intoned by all: "3/5 of their nervous system in the arms," etc.

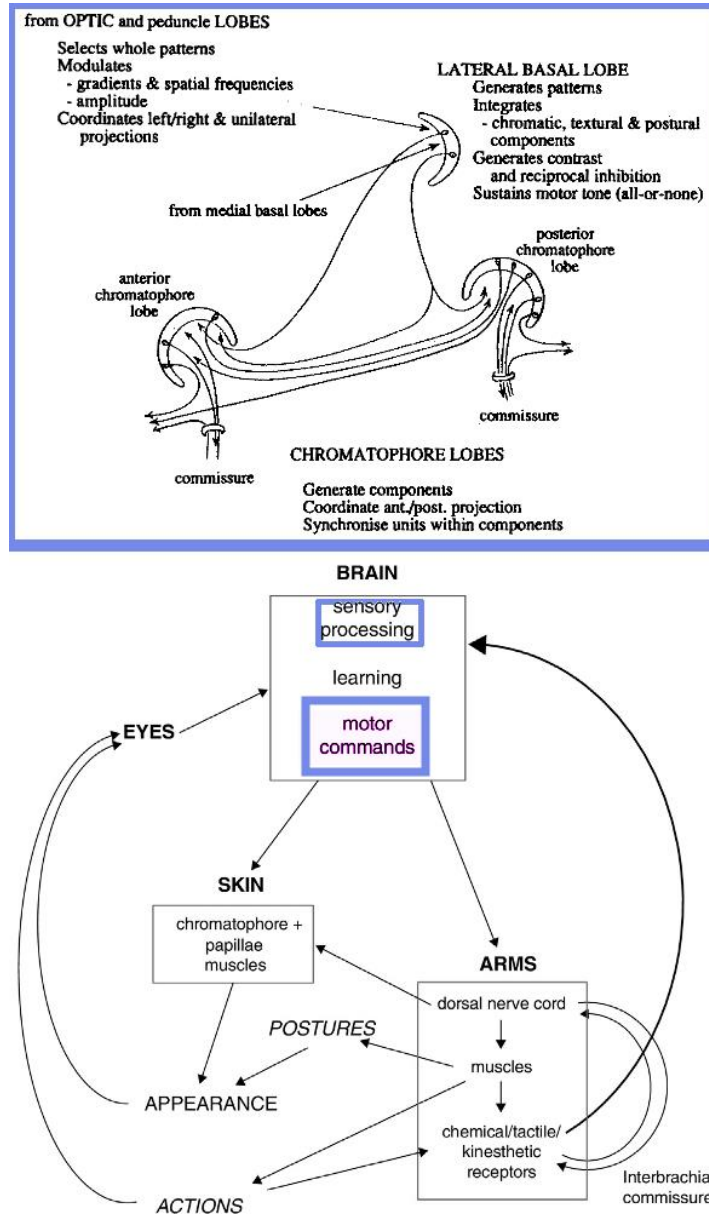


Figure 4. Summary of functional levels controlling motor output of the chromatophore system (Boycott 1953; Packard 1995a, pp. 358-361) (above, blue; Packard 1995b) superimposed over the corresponding box in Mather's alternative scheme (Mather & Dickel 2017) (below).

Young makes it abundantly clear that “considering how they have arisen in evolution as they still do in ontogeny today” (Young 1971, pp. 5-10), the large optic lobes belong with the rest of the supra-oesophageal mass. The commissures directly linking them across the midline pass through it. Analogous to the optic commissures of insects with their huge eyes, commissures uniting the optic tecta of fish and paired cerebral structures elsewhere in the animal kingdom (mammalian *corpus collosum* included) are missing from Figure 5 (below) and other versions of the same diagram. Yet transverse sections of a freshly hatched octopus would be a simple class exercise to check for their presence.

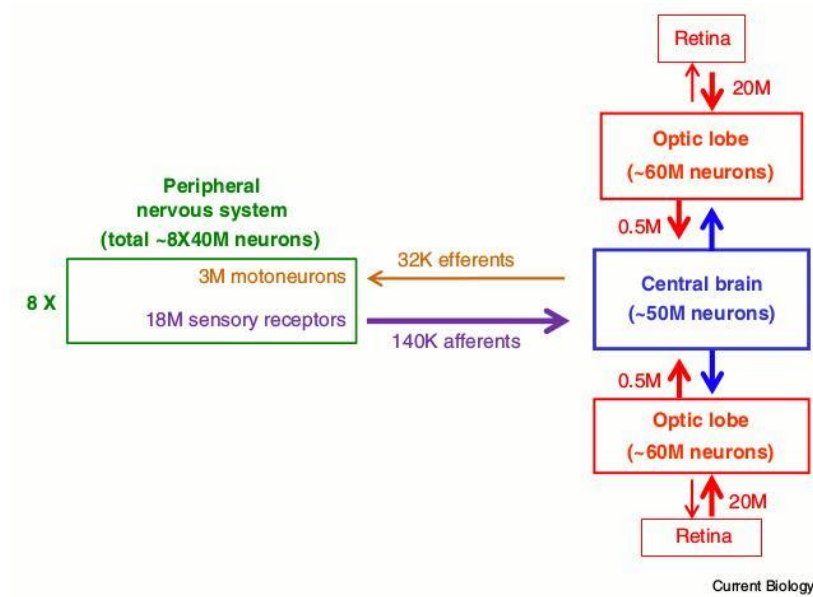


Figure 5. (from Hochner 2012, figure 1) Two huge optic lobes serving bilateral eyes in a box that is separate from that of a 'central brain' in the middle of the head; arm nerve cords (labelled 'peripheral nervous system') are a third box. Young's neuron counts are appended.

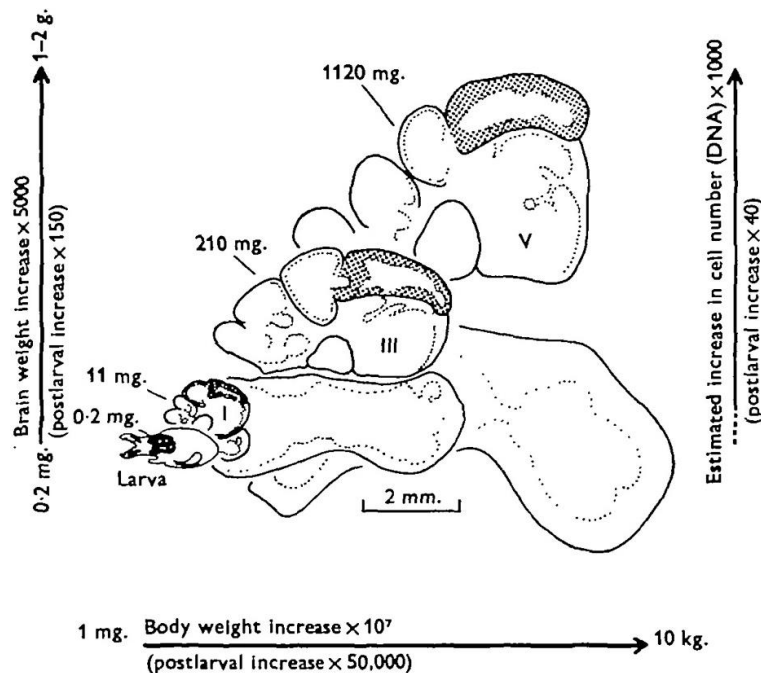


Figure 6. Body-weight groups indicated by sagittal brain section outlines (from Packard & Albergoni 1970, p. 540).

Figure 6 (above) puts Young's (1963) estimates in ontogenetic perspective. Over the potential life history, from first settling on the sea floor to old age, that *O. vulgaris* specimen (probably 200-500 g) would have increased in brain weight and non-polyploid ('diploid equivalent') amounts of

DNA (~numbers of cell nuclei) by orders of magnitude. At hatching (far left in Figure 6), half of all cell nuclei in the body are in a fast differentiating brain.

3. Feelings

Where are the feelings we have lost in sensation? Where are the sensations we have lost in sensory? (See last sentence of this commentary.)

The only work of mine cited by Mather in a 150-strong bibliography is Packard (1972). That paper is not a primary source for accounts of the brain, nor of the cephalopod chromatophore system. Sadly, its take-home message – that co-evolution of cephalopods and vertebrates over fossil time in what I called 'behaviour space', promotes further evolution of that space – has not really been understood by popularizers (Mather cites Godfrey-Smith, 2017). Mather's figure 4 draws attention to darkening on the left side of an octopus. Close inspection of the photo reveals an underlying 'mottle' pattern worn by both sides of the animal; darkening on its left side is due to one class of chromatophore activity only: neutral density screening (see Packard & Hochberg 1977a figure 1; [supplementary cuttlefish movie](#) for *Holes in the camouflage*; Packard 2010).

More directly relevant is a later review that tackles the otherwise studiously avoided subject of feelings and their role in shaping the biosphere: Packard & Dellafeld-Butt (2014) suggest that "it is love that makes the world go round!" while at the same time entering into nitty gritty details of brain chemistry. (Yet, astonishingly, feelings and emotions do not figure in the target article!)

Mather's question — "What is in an octopus's mind ... motivated to gather information" — belongs with the reductive bottom-up approach still dominating North American biology, an approach that deprives discussants of the appropriate language for talking about these things. 'Cognitive' will not do the trick. Nor 'embodiment', I find. My "Contribution to the whole (H)" (Packard 2006) arose from the need to interpret experimental observations on the properties of cephalopod skin when nervous control is absent or suppressed. The notion of 'horizontal control' offers a way around the bottom-up v. top-down difficulty. And helps to free language.

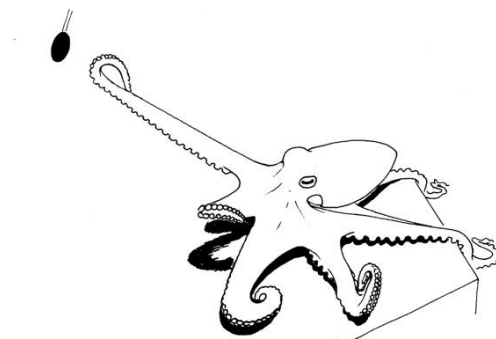


Figure 7. The last two of the series of 'vignettes' described in Packard & Dellafeld-Butt (2014) are Audubon's pair of passenger pigeons from the 19th century and my Naples octopus exhibiting conflict [perhaps worth a mention in an article on mind?]. The drawing also appears in the section on welfare of captive animals for the excellent OUP (Oxford University Press) *Very Short Introduction series: Animal Behaviour* (Wyatt 2017).

The young cat in Packard & Dellafeld-Butt's first vignette (p. 334), presenting me with kittens on my last night in New Zealand, had been brought as a kitten in order to save it from the attentions of his other cats at home, by A.K. McIntyre (neurophysiologist working with the decerebrate preparation). That empathy helped inform his laboratory research.

“Construction of models of how the brain works are well and good. But they must be firmly based on experimental observations and they are only as good as the questions they raise.” (Proske 2003; obituary for Archie McIntyre)

Brave of you, Jennifer, as well as thoughtful, to invite me to comment. [So may I be forgiven for lamely paraphrasing T.S. Eliot's “Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost in information” (*The Rock*)].

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