than from the larger terrestrial carnivorous pseudosuchians, most of which were in any case too late in time to be potential ancestors.

Though some problems have then, at least been tackled, one still cannot help feeling that just as a camel is said to be a horse designed by a committee, the pterosaur is the result of that committee turning its attention to birds. □

Fish vision discussed

from a Correspondent

THE thirty thousand or so living species of fishes inhabit a wider variety of visual environments than any other vertebrate group. Different water bodies vary widely in their colour and turbidity, presenting very different visual tasks to their inhabitants; many species migrate during their life span exposing themselves to these various environments; and there are also often marked seasonal changes in the water's quality. The fishes, therefore, form an ideal group for comparative studies of vision. If we add to this the fact that they are readily available and excellent subjects for physiological experiments, it is not surprising that a great deal of work has been done on various aspects of their vision. Some was reported at a recent meeting of the British Photobiology Society held in London*.

Anatomical papers on the retina (H.-J. Wagner, Universität Ulm) and on cone photopigments (J.N. Lythgoe, University of Bristol) made full use of the comparative approach, and showed that striking differences, clearly associated with the environment, may be found. Explaining their significance is, however, often more difficult. Why, for example, should fish living near the surface be less sensitive to long wavelength light than those that live deeper? They clearly are, though no one knows the reason.

K.H. Ruddock (Imperial College, London) presented results from experiments involving strong bleaching of the retina with a laser, a technique that can reveal receptor interactions that are normally concealed. R. Weiler (Universität München) then described his results on horizontal cells, which posed the unanswered conundrum of how a graded potential can be transmitted without degradation along 600 m of axon when theoretical considerations suggest 150 m should be the maximum possible distance. M.B.A. Djamgoz (Imperial College, London) and S.H. Reynolds summarized their work on possible retinal transmitter substances. A wide variety of possible transmitters exist: a list of some 30 candidates was given, of which the most likely ones are GABA and asparate. Although, however, the evidence is very suggestive, even in these cases it is not conclusive and much work, which should prove very profitable, clearly remains to be done.

These retinal studies used fish mainly because of their experimental convenience. Reports on the anatomy and physiology of the optic tectum followed in which fish were also used largely for this reason. In the complex analyses that the tectum carries out, however, the problems of the aquatic environment also began to reappear. For example, tectal units responding in a most striking way to very short wavelength light were described for the perch, which is surprising in a fish that does not possess blue cones, has a yellow cornea, and lives in coloured water in which short wavelength light is almost totally absent. Other units that respond preferentially to repeated stripes were described for this species: could these be related in any way to the fact that the perch itself is striped?

Two papers reported laboratory behavioural studies on spectral sensitivity in fish. W.R.A. Muntz (University of Stirling) reported data that compared vision in an upward direction with vision downward: these showed marked differences in both absolute sensitivity and the form of the spectral sensitivity curve, which may plausibly be related to the difference in the amount of light reaching the fish from the two directions. C. Neumeyer (Institüt für Zoologie, Mainz) presented spectral sensitivity data for goldfish. One striking and confusing fact about behavioural studies is that whenever the experimental situation is changed the results also usually change, and these results were no exception to this rule. Presumably different neurones, with different sensory inputs, contribute preferentially to different behaviour patterns. □

*The Visual System of Fish, organized by M.B.A. Djamgoz (Imperial College, London) was held at Imperial College on 27 February, 1980.

Polarity of spindle microtubules

from Jeremy Hyams

UNLIKE microfilaments in which directionality can be visualised directly by specific interaction with heavy meromysin, the polarity of microtubules has, until now, been approachable only by more devious methods. The most successful has exploited the ability of tubulin subunits with attenuated capacity to self-assemble, to polymerize *in vitro* onto some preformed seed or organizing centre. Various cellular structures will apparently serve although most frequently used are flagellar axonemes from the green alga, *Chlamydomonas,* whose two ends are morphologically distinguishable. When axonemes are incubated with low concentrations of brain tubulin (<2 mg ml^{-1}), microtubules grow by the addition of subunits onto the distal end only. At higher tubulin concentrations, growth is onto both ends of the axoneme although the rate of subunit addition at the distal end is at least three times that at the proximal (Allen & Borisy *J. molec. Biol.* **90,** 381; 1974; Binder *et al. Proc. natn. Acad. Sci. U.S.A.* **72,** 1122; 1975). This directional polymerization is taken to reflect an intrinsic molecular polarity within the microtubule structure, that is, the asymmetric tubulin subunits are all oriented in the same way along the microtubule axis, an arrangement also inferred from detailed analyses of microtubule structure by electron microscopy and optical diffraction (Amos & Klug *J. Cell Sci.* **14,** 523; 1974).

Microtubule polarity has been a central concern in studies of mitosis ever since a suggestion made over a decade ago by McIntosh, Hepler and van Wie (*Nature* **224,** 659; 1969), that the polar functions of the mitotic spindle in mammalian cells might reflect an antiparallel relationship of microtubules originating from the polar centrosomes and the chromosomal kinetochores. The subsequent demonstration by many workers that both of these components would nucleate the assembly of neurotubulin in cell-free systems (McGill & Brinkley *J. Cell Biol.* **67;** 189; 1975; Snyder & McIntosh *J. Cell biol.* **67,** 744; 1975; Telzer *et al. Proc. natn. Acad. Sci. U.S.A.* **72,** 4023; 1975) appeared, at least superficially, to be consistent with the McIntosh *et al.* model.

A more recent series of papers from Margolis and Wilson, however, has struck a discordant note. On the basis of an analysis of the exchange of [^{3}H]GTP with microtubules assembled to steady state, these workers have proposed a novel mechanism of microtubule assembly whereby subunits are added to one end of the microtubule and removed at the other in a unidirectional (opposite end) assembly and disassembly process (*Cell* **13,** 1; 1978). The result is a continuous flow, or 'treadmilling' of subunits along the microtubule at a rate measured to be 0.69 $\mu m\ h^{-1}$. Extrapolation of these findings to

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