

signal-to-noise ratio. Nonetheless, at this speed the visual system can distinguish two intervals that differ spatially by less than 0.5 arc min (less than the spacing between cones), and temporally by only 1.4 ms. We contend that reliable extraction of detailed pattern information from moving images would be extremely difficult unless the visual system can make spatial comparisons that take into account the temporal delay at which different photoreceptors have been stimulated. This is the essence of any motion deblurring process^{2,6}.

Morgan and Benton confirm previous reports that Vernier acuity is only minimally degraded by image motion, and they interpret this by proposing that orientation-selective cells are exquisitely sensitive to the relative timing with which different parts of the receptive field are stimulated. This mechanism is tantamount to a form of motion deblurring as defined above. The need for it arises because Vernier acuity is more strongly impaired by static spatial blur^{4,7} than by motion blur.

Motion deblurring is but one example of visual processes that may involve dynamic transformations of the frame

of reference within which images are analysed⁶. Strategies for the dynamic control of information flow, such as that provided by putative neural 'shifter circuits' (ref. 8), may provide powerful means of overcoming the limits of fixed connectivity in biological systems, thereby improving the efficiency and accuracy of neural computations.

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Ecological power laws

SIR—Cohen¹ has commented that there is as yet no mechanistic explanation for the empirical ecological proportionalities observed by McNaughton *et al.*². The prospect of "linking previously known structural regularities in plant and animal ecology with new functional patterns" may be less distant than Cohen fears.

The simple power-law relationships reported by McNaughton *et al.* are between the biomass and activity of herbivores in a given ecosystem, and various measures of the annual productivity of the vegetation on which the herbivores graze. There is another example of an empirically observed proportionality in natural communities. This is the observation that in mature plant stands the mass of plant tissue per unit area varies as the $-3/2$ power of the number of plants per unit area^{3,4}. The relationship, known as the ' $-3/2$ power law', has attracted various attempts at a mechanistic explanation. Here I show that the data assembled by McNaughton *et al.*¹ conform rather closely to one of these mechanistic explanations, the so-called core-skin hypothesis⁵. This postulates that plants function as a thin and energetically active skin over a massive and inactive core. The inactive core (xylem) is evidently 3-dimensional; the active skin (leaf, phloem and stem cortical tissues) is assumed to be 2-dimensional. The $-3/2$ power law follows directly from these assumptions⁵.

To a first approximation we may equate the annual production of 'skin' with McNaughton *et al.*'s net productivity of foliage (NFP); the annual production of 'core' with McNaughton *et al.*'s net primary productivity (NAP). McNaughton *et al.* report the following relationships between NFP, NAP and C (annual consumption of vegetation by herbivores):

$$\begin{aligned}\log C &= 1.38 (\log \text{NAP}) - 2.32 \\ \log C &= 2.04 (\log \text{NFP}) - 4.80\end{aligned}$$

The units are $\text{kJ m}^{-2} \text{yr}^{-1}$. Eliminating C, we have

$$\log \text{NFP} = 0.677 (\log \text{NAP}) + 1.22$$

Thus McNaughton *et al.*'s data suggest that NFP varies as the 0.677 power of NAP. The theoretical prediction from the core-skin hypothesis is 0.666. It would of course be better to estimate the relationship between NFP and NAP directly but the agreement between observation and prediction is striking.

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Hiccups and human purpose

SIR—Hiccupping is a reflex consisting of spasmodic bursts of inspiratory activity followed within 35 milliseconds or so by abrupt glottic closure, so that the ventilatory effect is negligible¹. It is a universally experienced phenomenon², but is also pathologically associated with brainstem lesions^{2,3}, metabolic upsets² and some upper gastrointestinal disturbances². Hiccups have been contrasted with obviously useful reflexes (such as the cough and the sneeze) as being of no positive function^{1,2}. The hiccup has also been suggested as the vestige of a primitive reflex act from other primates, the significance of which has now been lost¹.

I have recently been conducting a small sample study of percutaneous fetal assessment ($n=1$). I have occasionally observed a regular repeated movement, apparently involving the trunk of the fetus. The subject's mother assures me that this is the subject hiccupping. Fetal hiccupping⁴ was reported in 1899 and confirmed after the development of ultrasound⁵ and may occur for up to 1.2% of intrauterine time⁶. This persists into neonatal life, when it has been calculated as occurring 3,000 times more often than in adults⁷. It has been suggested that fetal hiccups represent early respiratory movements in preparation for extrauterine life⁴.

I wish to propose that fetal hiccupping is a useful reflex to allow vigorous exercise of the respiratory inspiratory muscles without the inhalation of liquor. Immobilization of fetal muscle leads to disruption of development⁸ or atrophy, so that movement is required for normal development. Thus hiccupping, being the only opportunity for maximal inspiratory movement, is an essential and universal fetal reflex. The mechanism for the inhibition of this reflex in adults is not known, though one may speculate that it might be related to the changes in blood gases which alter the hiccup threshold experimentally¹.

The hiccup should be reclassified as an essential normal intrauterine reflex that may recur, like other primitive reflexes, in adult life.

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