are generated by multiple thalamic inputs that have temporally different responses to the stimulus (Fig. 1). Thalamic inputs that respond slowly to visual stimuli generate slow responses in cortical regions, whereas those responding faster generate fast responses.

Lien and Scanziani's results, taken together with previous work[3–10], raise the interesting pos-sibility that cortical direction selectivity is gen-erated through a common mechanism — the convergence of temporally diverse thalamic inputs — in rodents, cats and primates. But as with all research, some questions remain open.

For instance, the authors focus their study on the middle layers of the visual cortex, which receive the bulk of the thalamic input[11]. As Lien and Scanziani show, many thalamic inputs in these middle cortical layers are not direction selective, but their combined activity is. It remains unclear whether thalamic inputs that target other cortical layers (or serve other functions) can encode direction selectivity through different mechanisms. For example, neurons in the superficial layers of the cor-tex might derive their direction selectivity from thalamic neurons that are themselves direction selective[12].

It is also known that thalamic inputs to the visual cortex are arranged by their receptive-field position — inputs that have receptive fields close to one another in the field of view are clus-tered together. However, it is not yet known whether the thalamic inputs are also arranged according to their temporal properties. If so, this could explain why spatial position and direction preference tend to change together in different neurons across the visual–cortical map[13].

Whatever the answers are, it is becoming increasingly clear that the visual cortex generates stimulus selectivity, such as preferences for direction and orientation, through thalamo–cortical convergence. Lien and Scanziani's work shows that this mechanism is better preserved across mammals than was previously thought. ■

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ENGINEERING

Two artificial synapses are better than one

Emerging nanoelectronic devices could revolutionize artificial neural networks, but their hardware implementations lag behind those of their software counterparts. An approach has been developed that tips the scales in their favour. See Article p.60

GINA C. ADAM

Inspired by the brain's neural networks, scientists have for decades tried to construct electronic circuits that can process large amounts of data. However, it has been difficult to achieve energy-efficient implementations of artificial neurons and synapses (connections between neurons). On page 60, Ambrogio *et al.*[1] report an arti-ficial neural network containing more than 200,000 synapses that can classify complex collections of images. The authors' work dem-onstrates that hardware-based neural networks that use emerging nanoelectronic devices can perform as well as can software-based networks running on ordinary computers, while consuming much less power.

Artificial neural networks are not programmed in the same way as conventional computers. Just as humans learn from experi-ence, these networks acquire their functions from data obtained during a training process. Image classification, which involves learning and memory, requires thousands of artificial synapses. The states (electrical properties) of these synapses need to be programmed quickly and then retained for future network operation.

Nanoscale synaptic devices that have programmable electrical resistance, such

50 Years Ago

Reading aids for the blind have so far involved the use of intact sensory pathways and have progressed little beyond Braille and tape-recorded "talking-books". Both these systems are quite expensive … and both are slow in terms of information transfer to the reader … At a recent meeting of the Physiological Society, Brindley and Lewin demonstrated a device for stimulating the visual cortex of man directly … Essentially it consists of an array of radio receivers, encapsulated in silicone rubber and screwed to the skull … Activation of a receiver stimulated the cortex: transmission was in the form of a train of short (200 μs) pulses … it does at least seem feasible to transmit visual information directly to the central visual pathways of the recently blind.

From *Nature* 8 June 1968

100 Years Ago

It happened last week that about 1 lb. of fresh lamb was put into an oven at night in order that it might be cooked by morning on the "hay-box" principle. It was in a casserole, with a little water. Similar