Neurobiology and Human/Animal Behaviour
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problem set #3 solutions

MOTOR SYSTEM

1. The proteins responsible for muscle contraction are actin and myosin. They bind to each other and ratchet up.

2. Fast fatiguable fibres: glycolytic, fast, strong.
Slow fibres: aerobic, weak.
Fast fatigue-resistant fibres: intermediate.

3. 'Open-loop' is a silly term, since there really is no loop involved: in an open-loop system, there is no feedback from the output back to the control; the control must make an accurate prediction of the effect of its output.

4. Spasticity is abnormally high stretch resistance, due to absence of the motor command signal. Myoclonus is oscillation due to abnormally high sensitivity to negative feedback which leads to overcorrection.

5. Renshaw cells, located in the ventral horn of the spinal cord, provide negative feedback to the muscles.

6. Loop delay is the interval between the time at which the control system issues a command and the time at which feedback signals describing the effects of that command arrive back at the control. The vestibulo-ocular reflex uses vestibular input to produce oculomotor output that will hold the position of images on the retina steady by compensating for movement of the head. The slip of the image on the retina serves as a feedback signal. Because retinal photoreceptors are slow, the loop delay is large; the feedback signal cannot arrive in time for it to be useful in correcting the magnitude and direction of the reflexive eye movement and therefore the vestibulo-ocular reflex must be open-loop. The feedback signal is used, however, in modifying the gain of the reflex so that future responses will be more accurate.

7. Simultaneous stimulation in this example would evoke a saccade to $(0°, 5°)$, the vector sum of the loci of the two stimulated sites. Population coding in the superior colliculus seems to represent saccade targets as vectors.

8. Efference copy is a duplicate of the command signal which is sent to an auxiliary system. This auxiliary system quickly models the behaviour of the effectors, and returns a prediction of the effectors' behaviour in response to the command. The control then uses this prediction as a feedback signal to modify its command signal. Thus efference copy sent through the auxiliary predictive system can serve as a substitute or supplement for true closed-loop feedback. In the motor system, the cerebellum serves as such an auxiliary processor of efference copy relayed via the pons.

9. From cerebral cortex, efference copy passes through the pons and then via mossy fibres to the granular layer of the cerebellar cortex. Each granule cell sends out an axon which ascends into the molecular layer and then bifurcates into two branches running medially and laterally. These parallel fibres synapse with the dendritic trees of Purkinje cells, which send inhibitory projections to the cerebellar deep nuclei. The deep nuclei consist of the globose and emboliform nuclei medially, known collectively as the nucleus interpositus, and the much more extensive dentate nucleus laterally. (The denate is not to be confused with the hippocampal gyrus of the same name.) The deep nuclei in turn project back to the cerebral cortex via the thalamus.

10. Since movements are represented by population coding, a small stroke decreases the number of cortical columns signalling the movement (and thus the amplitude of the signal), but doesn't affect the signal's mean locus within the somatotopic map.

11. The corpus striatum, consisting of the caudate nucleus medially and the putamen laterally, is so named because its two components are separated by the white matter of the internal capsule which streams in between them.

12. The thalamic lesion interrupts a cortical feedback loop that extends through the substantia nigra, the striatum, and the globus pallidus. The pallidal lesion acts more specifically by eliminating excessive inhibition of the thalamus.

13. The cerebellum is a computational structure that predicts the future state of the cerebral cortex on the basis of its current outputs. It's involved in predictive and preparatory processing during motor activity and also during cognitive activity. When the cerebellum is damaged, both motor and cognitive operations can still be implemented, but they become slow,

articulated, effortful, and error-prone. In addition to the most common and obvious symptoms of ataxia, cerebellar damage can produce transient mutism and difficulty shifting attention.

VISUAL SYSTEM

1. Myopia is a lack of focus due to elongation of the eyeball. Presbyopia is a lack of ability to accomodate to close objects, due to increased rigidity of the lens.

2. Strabismus, in general, is a failure of the oculomotor system to cause the eyes to converge on the same point in space. Accommodative strabismus, in particular, is strabismus that appears as a consequence of accommodation. The oculomotor system uses a single signal to drive three processes that are necessary for accommodation: the lens must be made more convex in order to increase its optical power, the pupils must be constricted in order to improve depth of field (as in a pinhole camera), and the eyes must be turned inward so that they converge on a point close to the head. It is this last component of the accommodation response, adjustment of the vergence angle, that is involved in accommodative strabismus: if the magnitude of the response in the two eyes doesn't match, the eyes will fail to converge.

3. 11-cis-retinal absorbs a photon and becomes all-trans-retinal, bound to rhodopsin. This complex activates transducin, a G-protein which in turn activates a phosphodiesterase that hydrolyses cyclic GMP. The resulting decrease in the concentration of cyclic GMP closes cGMP-gated cation channels, hyperpolarising the receptor.

4. In darkess, channels are open, so calcium enters the photoreceptor. Calcium inhibits guanylate cyclase, resulting in a decrease in cGMP and a consequent bias towards the closing of channels. In light, conversely, there is less calcium entry, more guanylate cyclase activity, and so a bias towards channel opening.

5. Selective degeneration of horizontal cells could be expected to produce a loss of visual acuity due to absence of lateral inhibition.

6. A selective lesion of layers 1 and 2 (the magnocellular layers) in the left ventral LGN could be expected to produce a loss of motion sensitivity in the right hemifield.

7. The line of Gennari is a thin band of white matter sandwiched in layer 4 of primary visual cortex (Brodmann's area 17). It arises from the heavily myelinated inputs to visual cortex that terminate in this layer.

8. Centre-surround cells respond most strongly to spots that exactly cover the centres of their receptive fields. Simple cells respond to oriented edges, and complex cells respond to moving edges. Theoretically, a simple cell might take input from several centre-surround cells with colinear receptive fields, and a complex cell might take input from several simple cells of the same orientation selectivity with slightly offset receptive fields.

9. Ocular dominance columns were identified by intra-ocular injection of tritiated thymidine, followed by autoradiography. Orientation columns were demonstrated by systemic administration of 2-deoxyglucose followed by exposure to selectively oriented edges and then autoradiography. More recently, both sorts of columns have been mapped in humans using high-resolution functional magnetic resonance imaging.

10. Amblyopia is a permanent loss of acuity in one eye which can arise if that eye does not provide proper input during early life. It's only during early life that the visual system is plastic enough to alter its architecture in response to input patterns, and in fact, proper development of the visual system depends on its having properly patterned input. If signals from one eye are absent or otherwise uncorrelated with more robust signals from the other eye, the majority of the visual system will grow to respond just to the 'good' eye. Even if vision can be restored in the 'bad' eye in later life, visual acuity will never be normal since the developmental change in the visual system will have become permanent. The possibility of amblyopia has clinical implications: in cases of congenital strabismus, for example, it is imperative that corrective surgery or prism lenses be applied early in life so that normal binocular vision can develop.

11. This patient's optic chiasm has been sectioned in a sagittal direction. The injury affects only the crossing fibres from the nasal hemiretinas, leaving the ipsilateral fibres from the temporal hemiretinas intact.

12. The visual field is represented right-to-left and upside down in primary visual cortex. A lesion in the left inferior bank of calcarine sulcus will therefore produce a scotoma in the right superior visual quadrant.

13. Prosopagnosia, the selective inability to recognise faces, suggests a lesion in fusiform gyrus. This inferior occipitotemporal region may be particularly affected by vascular accidents in distributions of the basilar or posterior cerebral arteries.

14. Blindsight is the ability to localise simple optical phenomena without conscious awareness. Patients deny having the ability to locate flashes of light, but when asked to 'guess' they are able to point to the correct locations. Two ideas have been proposed to explain this phenomenon. In one view, unconscious visual perception may arise from the subcortical projection from the retina to the superior colliculus, which in turn communicates with regions of the parietal lobe associated with spatial attention. This retinotectal pathway is actually the primary optical pathway in reptiles, amphibians, and birds, but has been superseded in mammals by the newer, retinothalamic route of the optic nerves and optic tracts. In the second view, spared islets of primary or early secondary visual cortex may provide enough signal to affect behaviour but not enough to drive conscious awareness. Clinical lesions are rarely 'clean', and islets of cortex often are spared from the effects of a stroke.