Neurobiology and Human/Animal Behaviour
Matthew Belmonte
problem set #4

Relevant readings:
Kandel & Schwartz, chapters 32 & 33 – for an overview
Moore, *Introduction to the Psychology of Hearing* 4/e (Academic Press, 1997) – for details
Zwicker & Fastl, *Psycho-acoustics: facts and models* 2/e (Springer-Verlag, 1999) – for esoterica

1. What is a decibel?

2. What role does impedance matching play in the function of the middle ear? What are the two substances whose acoustic impedances are being matched?

3. What are the mechanical relationships between the oval window, the round window, the scala vestibuli, the scala media, the scala tympani, and the helicotrema? What structures separate the scalae?

4. In what specific anatomical structure are inner hair cells found? By what mechanism do they transduce mechanical oscillations into voltage oscillations?

5. What is frequency masking?

6. The minimum audible field (MAF) is the lowest-amplitude sound (generally measured in dB SPL) that can be heard by a normal human listener, as a function of sound frequency. It's measured by placing a microphone at the position that has been occupied by the centre of the listener's head. The minimum audible pressure (MAP) is the same, but measured by inserting a very small microphone into the auditory canal so that it's not quite touching the tympanic membrane. Though the MAF and the MAP are quite similar, they do differ importantly around 4 kHz, where the MAF is lower than the MAP. What produces this difference, and what conjecture can you offer as to why it evolved? (What sorts of sounds are important to primates?)

7. The distance between the ears is about 0.6 foot. The speed of sound in air at sea level is 1116.45 feet per second. Localisation of low-frequency (less than about 4kHz) sounds therefore depends on the discrimination of

inter-aural phase lags of about half a millisecond or less. Neurotransmission takes about 10 to 20 milliseconds. How can these facts be reconciled? (Think about a similar situation in the visual system: even though foveal receptive fields are about half a degree wide, features much smaller than this can be discriminated.)

8. In what midbrain nucleus is inter-aural phase lag computed?

9. Why can't phase lag be used to localise high-frequency sounds?

10. Through what structures does the neural representation of sound pass on its way from the cochlea to primary auditory cortex?

11. A digital signal consists of a series of discrete steps in amplitude over time, where the minimum height of the steps corresponds to the number of discrete levels allowed by the digital representation. The more bits are used, the more levels are available. So, for example, 8 bits give $2^8 = 256$ possible levels, whereas 16 bits give $2^{16} = 65536$ possible levels. If too few bits are used, the digitised signal sounds noisy, as if a low-amplitude square wave has been superimposed on the original, smoothly varying signal. If too many bits are used, then computer memory is wasted and your MP3 player can't store as many songs. With your knowledge of the human auditory system, can you think of some methods that MP3 encoding software might use to decide how many bits of digitisation to use?