Su et al (2009)

(5 points) Why is it difficult to understand olfactory neural encoding compared to other sensory modalities, such as vision or olfaction?

Olfactory neural coding is more difficult than other sensory modalities, because it detects stimuli that require multiple odor receptors to identify a specific odor molecule, requiring odorants to bind to the correct ORN (Su, pg. 1). Whereas in sound, the input is only one dimensional through the tympanum (Grothe, pg. 2).

(5 points) Explain the relationship among physical space, neural space, and perceptual space in olfactory processing.

The physical odor space is how an odorant is represented through its parameters, including carbon-chain length, molecular weight, and polarity, and other molecular features. The neural odor space is how this odorant is represented with the olfactory system, through the response of the ORNs (su, pg. 11). Perceptual space is how an animal interprets the smell, how it compares to other similar smells and differentiates between different smells. (Su, pg. 4)

(10 points) Enumerate three ways in which the olfactory system limits the temporal extent of neural response to an odorant. (Extra credit: 10 points) Describe two computational benefits that may result from this feature.

Three ways the olfactory system limits temporal extent of neural response:
1. When an odorant binds to the OR, the binding is loose, due to hydrophobic and van der Waals interactions, so that the odorant dwell times are short. (Su, pg. 6)
2. The neural response of ORs decay quickly due to juxtaglomerular cells that inhibit ORN axon terminals. (Su, pg. 7)
3. Strong ORN activity depletes the synaptic neurotransmitter, so the transmission between neurons are decreased. (Su, pg. 8).

Two computational benefits of limiting the neural response:
1. The olfactory system can adapt to the environment, making it easier to detect novel smells that can signal important survival information.
2. Easier to determine relative difference, so can identify a concentration gradient for directional sense.

What is short-term synaptic depression and what is its proposed function in olfactory processing?

Short-term synaptic depression is the depletion of neurotransmitters that can be caused by high frequency sniffing, and causes depression in the OR of the presented odor, that can help in discriminating novel odors. (Su, pg. 10)

What is gain control and what computational function does it serve in the olfactory system?

Gain control is the ability to modify the input signal to the output signal. In olfactory systems, the gain control mechanism amplifies the input signal nonlinearly, so that high ORN responses do not saturate projection neuron responses. (Su, pg. 8)

(Extra credit) What is combinatorial encoding (5 points)?
Combinatorial encoding, in olfactory systems, is the mechanism that odors are encoded with several odor receptors. These are implemented with pyramidal neurons as coincidence detectors, that fire only when a certain group of receptors fire.

**Where is it found in the olfactory system (5 points)?**
Combinatorial encoding done by the pyramidal neurons are found in the piriform cortex. (Su, pg. 8)

**What are the computational advantage of combinatorial encoding (5 points for each correct answer, up to four).**
Combinatorial encoding allows for sparse coding, creating a neural code that represents some object.

*(Extra credit) What is "sparse coding" and how is it achieved in third-order neurons?* Sparse coding allows objects to be represented with a small combination of neurons. It is achieved in third order neurons by decorrelation of responses in the second order neurons, so that the fewer third neurons are activated with a more distinct activation pattern (Su, pg. 9).

*(Extra credit) What is "pseudogenization"? Give two examples in different species.* Pseudogenization is a process that mutates genes and renders them nonfunctional (not expressed in the cell). In dolphins, class II receptors are pseudogenized, and in humans, V2R genes are pseudogenized. (Su, pg. 4)

*Petersen (2007)*

**(20 points) Describe the pros and cons of each of the following technologies for measuring neural responses, and give specific examples in the study of rodent barrel cortex: multi-electrode arrays, intrinsic optical imaging, voltage-sensitive dye imaging, calcium imaging.**
Multi-electrode arrays are used to record action potentials from many neurons. In the rodent barrel cortex, whisker movement evoke action potentials on electrodes, depending on the location of the stimulated whisker. Pros: good temporal resolution. Cons: some spatial resolution (limited by electrodes), invasive.
Intrinsic optical imaging is used to record through the skull using physical changes in the blood flow. In rats, these are used by repeatedly deflecting a whisker and comparing changes in the image. Pros: non-invasive, high spatial resolution. Cons: poor temporal resolution.
In VSD imaging, a dye is applied to the cortical surface, and fluoresces to the membrane potential. Pros: High temporal and spatial, can visualize cortical columns Cons: Invasive. In rats, VSD shows that the neuron signal after whisker deflection propagates across the cortical map. Calcium imaging uses calcium-sensitive dyes to image network activity reflected by action potential firing. Pros: Can be used on brain slices or intact brain, Cons: invasive, Calcium imaging is used to show that neurons in layer 2/3 respond to whisker stimulation.