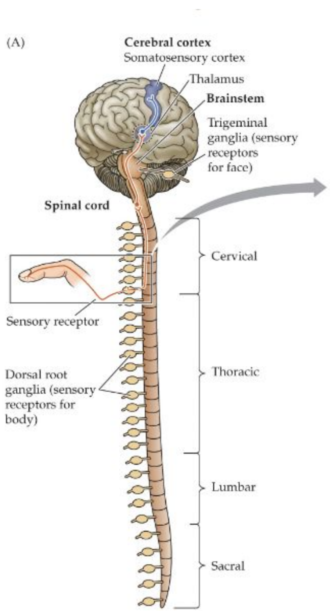
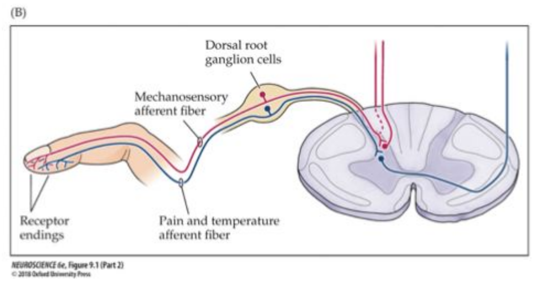
<u>BIO372 - LECTURE 3 - touch plasticity & pain</u>

Each spinal segment receives somatosensory inputs from a specific part of the body

- Afferent neurons that takes sensory information from the periphery and send it to the brain
- Neurons have cell bodies within the dorsal root ganglia and projected into the spinal cord
- There are ganglia all at these different positions along spinal cord and 1 per segment of the spinal cord



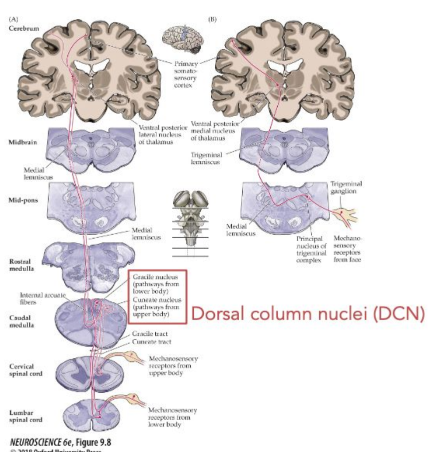


Each of the DRGs: **"Dermatomes"** refer to the areas of the body sending inputs to a specific segment of the spinal cord.

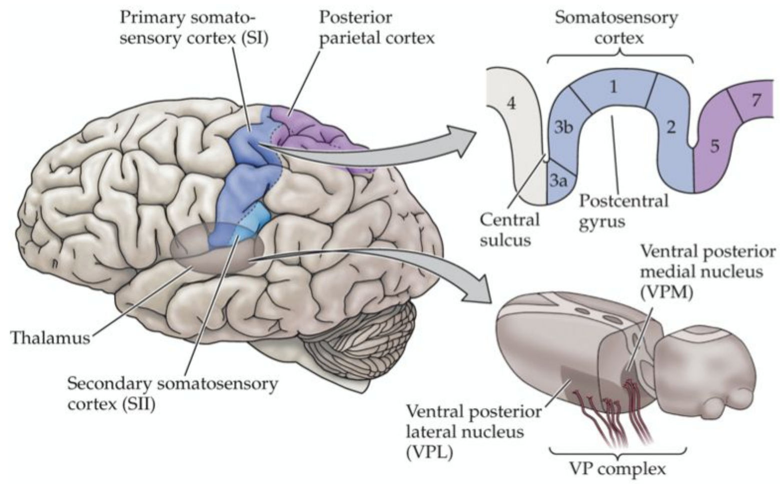
- Afferent neurons of that area innervate with the DRG from that segment of the spinal cord and project into that area of the spinal cord

Touch travels from receptors -> DRG neurons -> DCN -> thalamus ->cortex

- **Pathway leading from the periphery up to the brain underlying tactile sensation**
- **There is a separate system between touch sensation on body and on the head/face**



Touch information is represented in somatosensory cortex



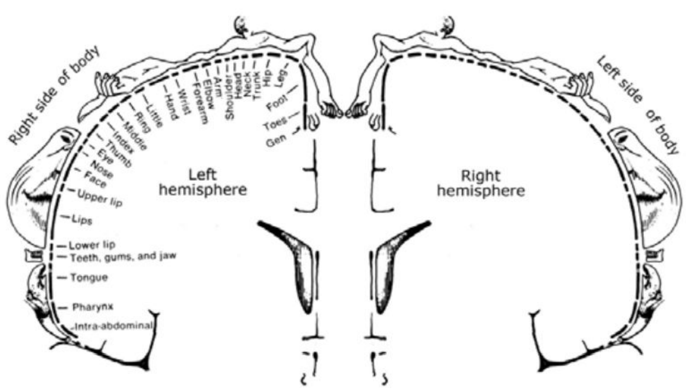
- Neurons carrying these tactile information synapse w/ neurons in the primary somatosensory cortex (SI)

Focusing: idea of touch representation in the cortex & circuits that underlie information processing in the system

Question: how touch perception is elicited in an animal?

- If you stimulate different areas of cortex in particular (somatosensory cortex) stimulation in the cortex is sufficient to elicit the perception of touch in the body.
- The perception of touch (actual feeling of touch) in your finger is completely generated by the activity in the cortex and this activity is sufficient to generate this perception

Cortical activity in S1 mediates the feeling of being touched



- Important discovery from pennfield: different positions on the body were mapped neighbouring positions in the somatosensory cortex
- Ex. if he stimulated an area that made the patient feel a touch on their finger and stimulated an area close to it, the patient would feel a touch on their hand

A fundamental question in neuroscience is how do animals 'know' the identity of a stimulus. In tactile sensation, one part of this question is how do we know where we are being touched.

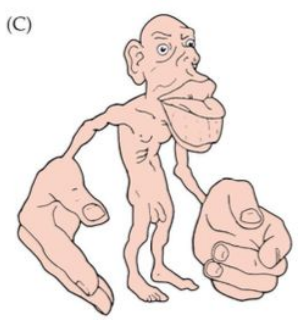
- Activity in the primary somatosensory cortex
- We will see throughout this course that the representation of a particular sense in
- The cortex is often organized according to some continuous parameter of the stimuli. In this example, that parameter is where the on the body touch occurs. The representation is called the **somatotopic map.**
- **Continuous parameter**

LO: Describe how tactile information is represented in the cerebral cortex.

- **"Represented": what is the pattern of neural activity in response to that stimulus?**
- **Ex. If you get touched on the finger, what is the pattern of neural activity in the primary somatosensory cortex that reflects that touch?**

Thought question: Why are certain body parts over- represented in the somatotopic map?

- Some are overrepresented in size and some are underrepresented in size
- Areas that are overrepresented are focus more on physical sensation, sensitivity and these areas have more sensory afferents from them, there are more touch receptors sending more information and so they need more neurons to process them in somatosensory cortex and this is why it is overrepresented in this area
- Flipside of this and the reason why there are more receptors in these areas because these are the areas that would benefit from higher tactile sensitivity/ tactile spatial acuity because these are the areas that are mostly used to touch things and would need to have fine discrimination of what you are touching



The homunculus ("little man")

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LO: explain how receptive field size influences spatial acuity

Precision of location coding is determined by receptive field size and density

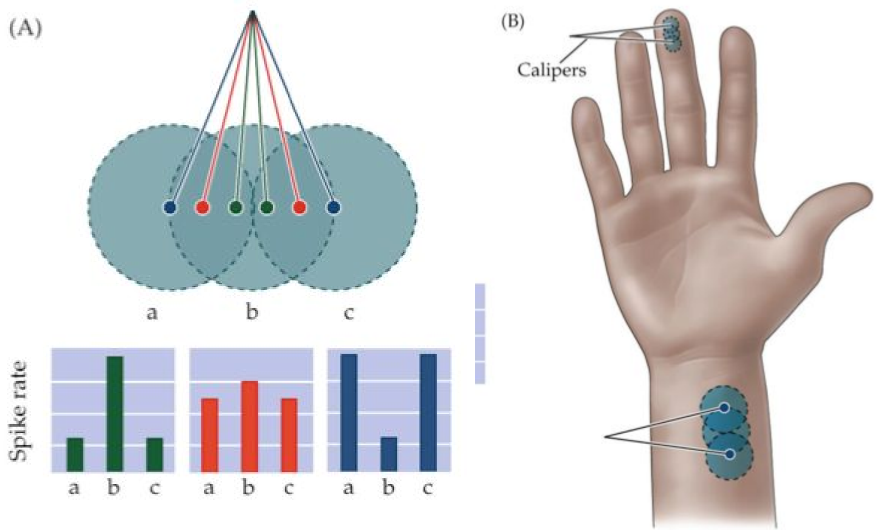
- This idea of spatial acuity can be defined by using spatial acuity test which is the two-point discrimination test
- If you take two needles and poke somebody really close together, they will only feel one touch and will not feel distinct pokes BUT if you move them slowly farther apart and keep poking, at some distance apart that person will perceive it as two distinct touched

- This distance apart/threshold where you distinct 2 different touches is the two-point discrimination threshold and this is a measure of spatial acuity
- The larger the space is the, the lower the spatial acuity and the smaller the space is the higher the spatial acuity - why is this?
    - The size of receptor fields in those particular areas and the density of the innervations of the neurons of these areas

• Receptive field of a neuron = the range of stimuli that activate that particular neuron -> it does not have to be an area of physical space, it could be on skin or it could be an area of space in visual field or 10 different odours a neuron responds to, or emotion.
(In the case of touch this is the area on the skin that activates the neuron)

Why would receptor field sizes affect spatial acuity?

• Spatial acuity is measured by two-point discrimination test
• Question is how far apart two touches need to be in order to perceive two touches rather than one.



(A): demonstrates why receptive field sizes affect spatial acuity -> there are 3 different neurons (a, b, c) and their receptive fields are shown by the big teal circles and the receptive fields are overlapping and it also shows 3 different pairs of touch which are colour coded - green touch is very close together than the red touch and blue is farther apart

- **When we stimulate the green touches that are closer together, we see most activity in neuron b with much less activity in a and c and this is why we only perceive it as one touch**
- **But when we move out to stimulating the blue touches, we can only see little activity in neuron b and much more activity in a and c -> now we can see that our brain can discriminate between these two touches because we have a separation in the representation (peak of representation of touch in neuron c and there's a**

valley of activity in neuron b so they are separate) -> and this is why we can discriminate them as two touches**
- **If you made the circles smaller, then the relative position of the 2 points also gets smaller and vice versa.**
- **This is why receptive field size underlies spatial acuity. Receptive fields on fingers are smaller than receptive fields in the wrist and this is why we have higher tactile spatial acuity on our fingers than the wrist.**
- **This effect does not depend on the gradient of sensitivity, just the size of the receptive field because as they get bigger, they get farther apart**

Spatial acuity differs between body areas

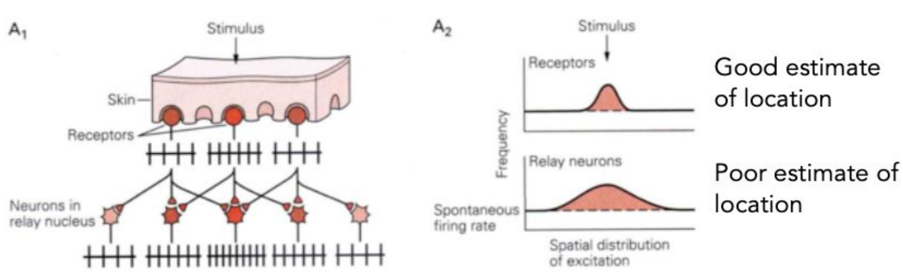
- Why is this a useful pattern to have? Why not just have high spatial acuity everywhere?
    - A downside: energetic expensive, overload of stimuli, requires a lot of neurons -> EFFICIENCY
    - Solution: we evolved to have high spatial acuity at some places
    - Fingers: 2-point discrimination is low

***LO: Explain the neural circuit mechanisms underlying spatial acuity*(important for exams)**

Tactile circuits help preserve spatial information as it travels from periphery to cortex

• Convergence – when a number of neurons converge on a smaller number of targets
• Divergence – when a number of neurons project to a larger number of targets.

Consequence in spatial processing:
Convergence and divergence will naturally blur positional information
• Feed-forward excitatory projections show extensive convergence and divergence, which on its own would blur maps and reduce spatial acuity.



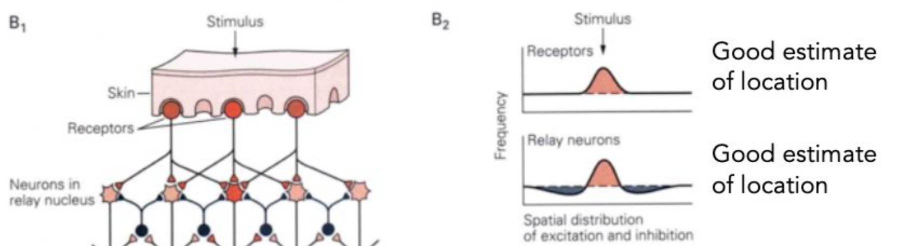
What does it do to an actual representation of touch?
- If stimulus is at neuron A, then in the receptor level (A2) the pattern of activity across the neurons in the skin,there is a very sharp peak of activity where the touch is so i gives us good estimate of location of the touch

- However, because we are now spreading the information out via divergence and also pooling information from different via convergence, if we look at the next level on graph, we see that representation has been spread out so it is no longer a good estimate of the location of the touch

Another mechanism that's layered on top of this that helps solve this problem -> Lateral inhibition: important neural circuit mechanism for fine tuning information and sharpening

Lateral inhibition sharpens representation

• The activity of each neuron excites GABAergic neurons, which inhibit neighbouring neurons
• This creates a "winner take all" scenario, where only the most strongly activated neurons show activity

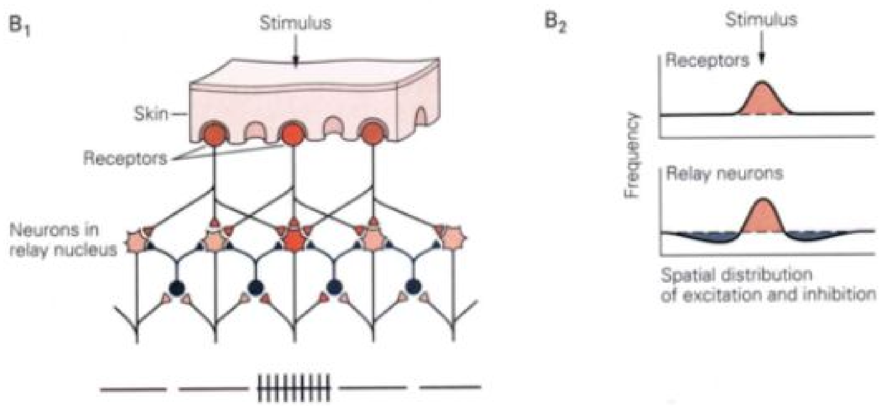


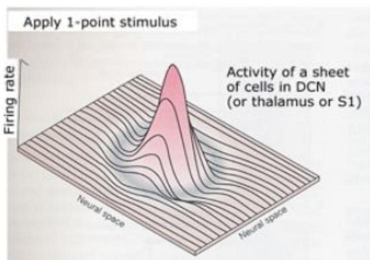
Note that lateral inhibition actually causes net inhibition of neurons in a ring around the excited neurons.

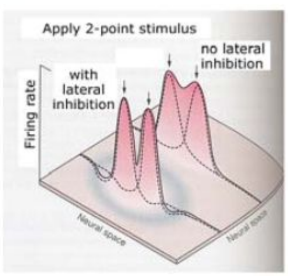
- Where they take where there is a strong signal (i.e middle neuron/neuron 3) and then this signal activates the lateral inhibitory neurons in the same region which then inhibits the other neighbouring neurons and as a result of this is you take the strongest signal and suppress everything around it creates a winner take all scenario instead of having a bunch of neurons firing a little bit, you take that peak firing and make it the winner and suppress the neurons around it
- What happens then is you go from this sharp peak in the sensory afferent neurons to having the same sharp peak that is surrounded by a ring of inhibition and this is also a good estimate of location
- In order to have convergence w/o divergence, we need more 1st level neurons/receptor neurons than the relay neurons
- To have divergence w/o convergence, we need more relay neurons that receptor neurons

Lateral inhibition enhances distinction between two neighbouring peaks of activity

- How does this all impact 2-point discrimination in spatial acuity?



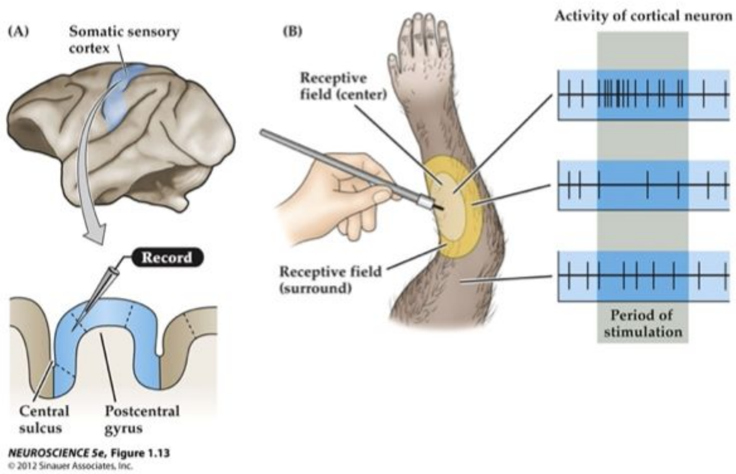




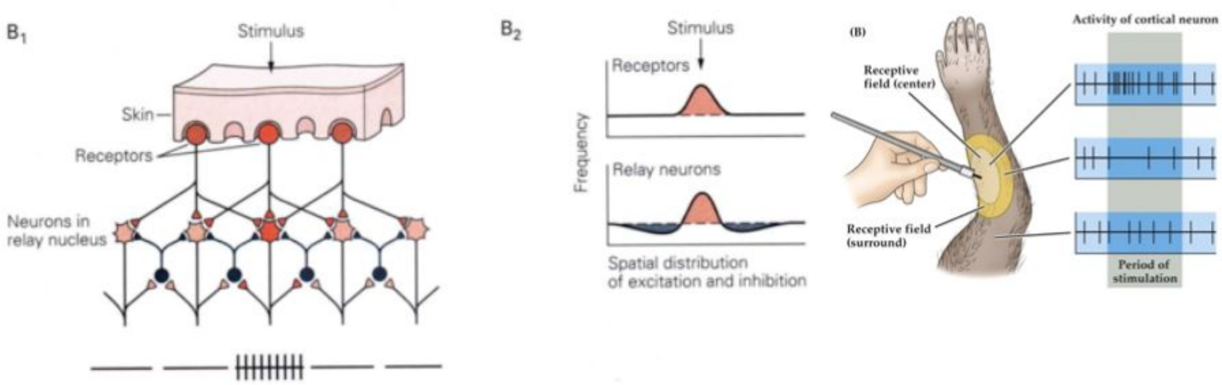
- If you have lateral inhibition to create a trough at each of the peaks then it much more easily creates a valley between 2 peaks when you have 2 touches
- Valley between 2 peaks is less pronounced
- This is why with lateral inhibition it will increase spatial acuity

The same lateral inhibition is also responsible for surround inhibition in touch receptive fields(looking at the representation of the field of touch in 2nd level vs whats the receptive field in one of these neurons)

- **Center excitation and surround inhibition**



- **Touching the center of its receptive field, it will get excited but not a touch in the surround (inhibitory surround of a receptive field)**



- **Activation of neuron B(middle) is going to mostly activate neuron 3 and cause a ring of inhibition in the neurons around it (2 and 4)**
- **If we look at neuron 4, it gets activated by touching neuron C but if you touch neuron B, neuron 4 actually gets inhibited**

These two phenomena are two sides of the same coin.
– On the left we are looking at how touch is represented across a field of neurons
– On the right we are looking at how touches in different places affect the firing of a single neuron
ARGUMENT: that lateral inhibition when you look at it from the perspective of the activity of field across neurons in response to a stimulus it is just the same thing but from a different perspective as looking as surround inhibition of a receptive field
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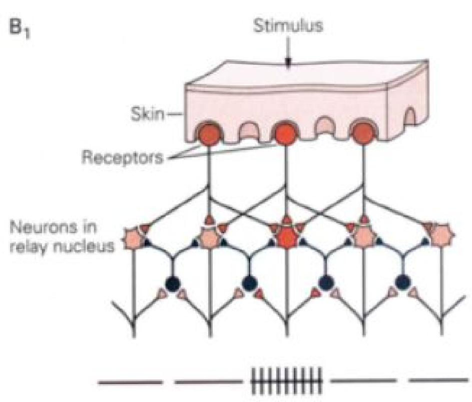
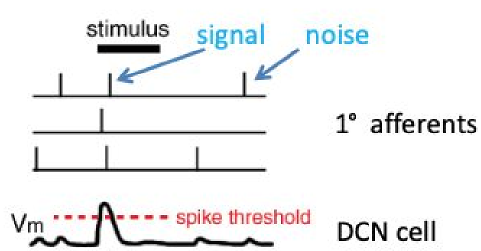
****REMEMBER: Why have circuits with convergence/divergence and lateral inhibition to basically offset the problems between convergence and divergence?**

- **Convergence performs an important function -> increase signal-to-noise - why?**
- **Neurons have a lot of noise to them always firing some level of spontaneous activity**
- **Noise: activity of an individual neuron that has nothing to do with the stimulus**
- **Signal: activity of the neuron in response to the stimulus**
- **Some spikes that are noise and each of them shows 1 spike in response to the stimulus**
- **The key thing here is that if there 3 neurons all synapsing to 1 downstream neuron, these 3 spikes in response to the stimulus all happen at the same time whereas the noise just happens at random**
- **But because the signal is in response to a particular stimulus, this is what causes for them to happen all at the same time**
- **DCN cell: 1 input cause depol that won't get threshold it can handle a little noise from 1 input it just causes graded potential but not spike but if having 3 inputs coming at the same time: spatial summation (sum all inputs and generate larger PSP above threshold, now DCN will spike and will tell the downstream system that it was a real touch)**
- **Instead of feeling like you're being touched all the time, you only feel touched when you're really touched because it activates a bunch of neurons simultaneously and the downstream neurons are filtering out that noise by only paying attention when a bunch of neurons are getting activated at once**
- **This is why we have this system -> increasing signal to noise ratio in the downstream neurons**
- **Higher the ratio, the more accurate the information is**





- Convergence promotes detection of small signals over noise, but degrades spatial information
- Convergence plus surround inhibition achieves both high sensitivity (high signal-to-noise) and good spatial localization

Cortical activity is ultimately the source of the feeling of being touched
We started this lecture with the idea of how we know where we are being touched.

LO: Predict the cortical changes that would take place upon removal of specific sensory input
The cortex remodels in response to changes in sensory input

- If the third digit on a monkey's hand is amputated, the representation of neighbouring digits expand into the space once occupied by neurons encoding sensations from the amputated digit.