1. A.

[Notice that a single action potential in the primary sensory neuron does not necessarily produce an action potential in the second neuron along the pathway.]

B.

[Notice there is not a 1:1 correspondence between action potentials in these two neurons.]

C.

[Notice that receptive fields are specific. Touching another finger has no effect on this neuron.]

D.

[Notice that the response is the same as to a gentle touch, in A, because the response of this receptor is specific to touch, not to temperature.]

E.

[Notice that the receptor potential is the same as in A, but there are no action potentials, because the voltage-gated Na+ channels are blocked.]
2. A. Pain is conducted in the anterolateral tracts contralateral to the side stimulated. Touch information is largely conducted in the dorsal columns ipsilateral to the side stimulated. Touch information carried in the dorsal columns crosses to the contralateral side in the medial lemniscus, after the first synapse in the dorsal column nuclei of the brain stem. Sensory information pathways intersect with motor pathways in the cortex. There also is some sensory-to-motor processing of information in the spinal cord, in spinal reflex arcs, and in the brainstem and thalamus.

B. This injury would block the conduction of most touch information from the right hand, but would leave pain information unaffected. Injury in C1 (the most rostral of the cervical spinal segments) would interrupt the conduction of information from the hand, because the hand is innervated by neurons that enter the spinal cord below C1. Most touch would be gone, because touch is carried in the dorsal columns ipsilateral to the source of sensory stimulation. Pain would remain, because it is carried in the anterolateral tract contralateral to the source of the stimulation. (Note: injury to a more caudal segment of the spine, for example T5, would leave all of the innervation of the hand intact, because the injury was below the point at which neurons serving the hand enter and leave the spinal cord.)

C. Severing the right cervical dorsal columns would not directly affect finger strength because no motor information is carried in these tracts. However, it could affect motor performance, because proprioceptive information (sensing position of parts of the body) is carried in the dorsal columns.

D. This injury would have little or no effect on information transfer from the right hand because such information is largely carried in the ipsilateral dorsal columns, with some carried in the contralateral anterolateral columns. No pain information from the right hand is carried in the left dorsal columns.

[DISCUSSION POINT: What would be impaired by this injury would be fine touch and proprioception from the left hand.]

3. How could spinal cord damage lead to loss of somatosensory perception, but leave muscle strength unimpaired?

If damage to the spinal cord destroyed only neurons or tracts that carried sensory information (mostly in the dorsal spinal cord) and spared the structures of the ventral spinal cord (both tracts and neurons), sensory perception could be significantly compromised without damaging motor output.
4. Ingesting muscarine, a molecule synthesized by some species of mushrooms, can be fatal if you eat too many of the mushrooms that make it.

a. Why could it be fatal to eat these mushrooms?

Activating muscarinic cholinergic synapses onto the heart slows the heart and can even stop it. If a large amount of muscarine were present, the heart could stop, or beat so infrequently that it was ineffective at moving blood through vessels. The heart itself would also soon become weakened, because it gets its own blood supply from blood vessels in its walls.

b. What symptoms would you expect to see in a person who mistakenly gathered and ate mushrooms that contain muscarine?

You would expect slow and irregular heart rate (because the muscarine mimics a strong parasympathetic nerve stimulation), and increased activity in the gastrointestinal system [which would cause diarrhea, vomiting, and copious salivation].

5. The movements of breathing are generated and controlled by neurons in several nuclei located in the brain stem. They are carried out by the diaphragm, a "voluntary" muscle that has NMJs like frog skeletal muscle and is not driven by autonomic neurons. Contraction of the heart, on the other hand, is initiated within the heart muscle itself and is modulated, but not initiated, by neurons of the autonomic nervous system. In each of your answers below describe the mechanism behind the effect that you predict.

a. When a South American native hits a deer with a blow dart poisoned by curare:

i. what effect will the toxin have on the deer's breathing?

In high enough doses, curare will block synaptic excitation of the diaphragm muscle, just as it will paralyze all other voluntary muscles, and breathing will stop. [The effective dose is in the range of 10^{-5} M; you can easily deliver a sufficient dose if you're good with a blow-dart.] As a result, curare will both stop breathing; the deer would die of suffocation.

ii. what immediate effect would you expect it to have on the heart rate?

Curare would have no direct effect on the deer's heart, because the ACh receptors on heart muscles are muscarinic.

iii. what effect would it have on the deer's ability to run away? Explain your answers.

Curare would block all the NMJs at skeletal muscles, which would paralyze the deer so it can't run away.
b. If curare was scarce, but mushrooms were plentiful, and an enterprising South American native used muscarine instead of curare, predict what direct effect the muscarine would have on:

i. the animal's breathing?

Muscarine would have no direct effect on the animal's breathing; all the muscles involved in breathing are nicotinic.

ii. the heart rate?

At high enough concentrations, muscarine would mimic the effect of the parasympathetic nervous system and slow the deer's heart rate.

iii. the deer's ability to run away?

Muscarine would have no direct effect on the animal's ability to run away; all the muscles involved in breathing are nicotinic.