View Attempt 3 of unlimited

Title:	**Quiz3**
Started:	November 28, 2010 11:47 PM
Submitted:	November 28, 2010 11:55 PM
Time spent:	00:07:39
Total score:	**57.13/68 = 84.0147%** | Total score adjusted by 0.0 | Maximum possible score: 68

Completed

1.

On October 31th, there was a M4.2 quake beneath the Hindu Kush in Afghanistan.

For more information, see:
http://neic.usgs.gov/neis/bulletin/neic_cyai_h.html

There are maps and other information on those pages (including historical seismicity maps).

From the location of the earthquake and its depth (see the map, you could plug the coordinates into Google Earth if you like), it was most likely related to:

	Student Response	Value	Correct Answer	Feedback
A.	Subduction thrusting in the overriding plate (likely thrust)			
B.	Transform motion (strike-slip faulting)			
C.	Ridgecrest spreading (normal faulting)			
D.	Subduction-related faulting within the downgoing			

	Student Response	Value	Correct Answer	Feedback
	plate			
E.	Thrust faulting in the lithosphere	100%	✓	yup. The crust is almost 70 km thick in that region. The lithosphere is quite variable in thickness, but it can extend to a good 200 km in places. The area is under compression. There will certainly be some strike-slip faulting due to angled compression, but the majority is likely to be thrust faulting.
F.	Subduction thrusting on the plate interface			

General Feedback: From looking at the region and plate maps, the earthquake occurred in the India-Eurasian continental collision zone. Collision - therefore compression - therefore thrust faulting should dominate in the central part of the region.

The earthquake was quite deep (45km), but that is within the thickened crust of that collision zone (where the thickest crust in the world is documented).

Score: 1/1

2.

This question involves identifying depth ranges for general types of earthquakes.

For earthquakes in a subduction zone (e.g., Cascadia, western South America, eastern Japan, etc.):

Statement	Response	Value	Correct Match
Depth range for earthquake foci within the downgoing (subducting) plate	From near surface to as much as 660-700km depth	33.33%	From near surface to as much as 660-700km depth
Depth range for earthquake foci in the overriding plate	Near surface to about 20-35 km depth	0.0%	Mostly in the crust, but extending into the lithospheric mantle.
Depth range for earthquake foci on locked plate boundary	Mostly in the crust, but extending into the lithospheric mantle.	0.0%	Near surface to about 20-35 km depth

General Feedback: Note: The 'great earthquakes' of high M8 to M9+ will only occur in the very shallow, locked part of the thrust interface. So, from about 0-20 km depth along the interface. But earthquakes can occur **within** the downgoing oceanic lithosphere to as deep as the lowest transition zone (~660 km).

If you look in the notes at the biggest earthquakes, all of the top 10 are convergent margins. 9 of those are quakes on the subduction megathrust interface. Only one in a continent-continent collision (Himalaya).

Score: 0.5/1.5

3.

The main reason that the lavas erupted from *island arc* and *continental arc* volcanoes are different is. *[select all correct answers. Points taken out for wrong anwers.]*

	Student Response	Value	Correct Answer	Feedback
A.	The formation location and composition of the initial magma formed is the same, but the overriding crust that the magma rises through is different.		☑	
B.	Island arc volcanoes should generally be more explosive.			
C.	The mechanism creating them is different. Continental arc volcanoes are caused by subduction melting.	-25%		

	Student Response	Value	Correct Answer	Feedback
	Island arc volcanoes are generated by hot spot plumes.			
D.	The formation location and composition of the initial magma formed is different. Since the rock is different that partially melts to form the magma, the chemistry of the lavas are different.	-25%		No. Both are 'arcs'. That means a long chain of volcanoes that are active at the same time. They are both caused by subduction. Make sure you know the difference between an island arc and a chain of islands caused by a hotspot.

Score: 0/1

4.

On April 24, there was a small (M3.3) quake in southern Quebec near Beaupre

For more information, see:
http://earthquakescanada.nrcan.gc.ca/recent_eq/2010/20100424.0708/index-eng.php

From the location of this earthquake, it was most likely related to:

	Student Response	Value	Correct Answer	Feedback
A.	Subduction thrusting on the plate			

	Student Response	Value	Correct Answer	Feedback
	interface			
	B. Transform motion between plates (strike-slip faulting)			
	C. Subduction-related faulting within the downgoing plate			
	D. None of the above	100%	✓	This earthquake was not on a plate boundary and is classed as an 'intraplate' earthquake.
	E. Ridgecrest spreading (normal faulting)			
	F. Subduction thrusting in the overriding plate.			

General Feedback: You can see there is a quake belt through eastern Canada that runs along the St.Lawrence and then south down into the US. This is not a plate boundary. These are intraplate earthquakes. Strain or deformation from the plate motions at the edges of the North American Plate are distributed across the entire plate. There are few earthquakes, but the plate does fail occasionally in places where it is weak. Part of this zone was a failed continental rift zone (~1 Ga). The St. Lawrence itself also represents a weak zone (likely an old major fault zone associated with the failed rifting or accretion on the eastern edge of the continent)

Score: 1/1

5.

The map shows the Juan de Fuca/Gorda plates that subduct under North America. This is the area called *Cascadia*.
The red lines are the ridgecrest (spreading-centre) segments, the dashed lines are the transform faults linking the ridgecrest segments. The black line with the triangles marks the trench - the place where the Juan de Fuca plate starts dipping beneath the overriding continental plate.

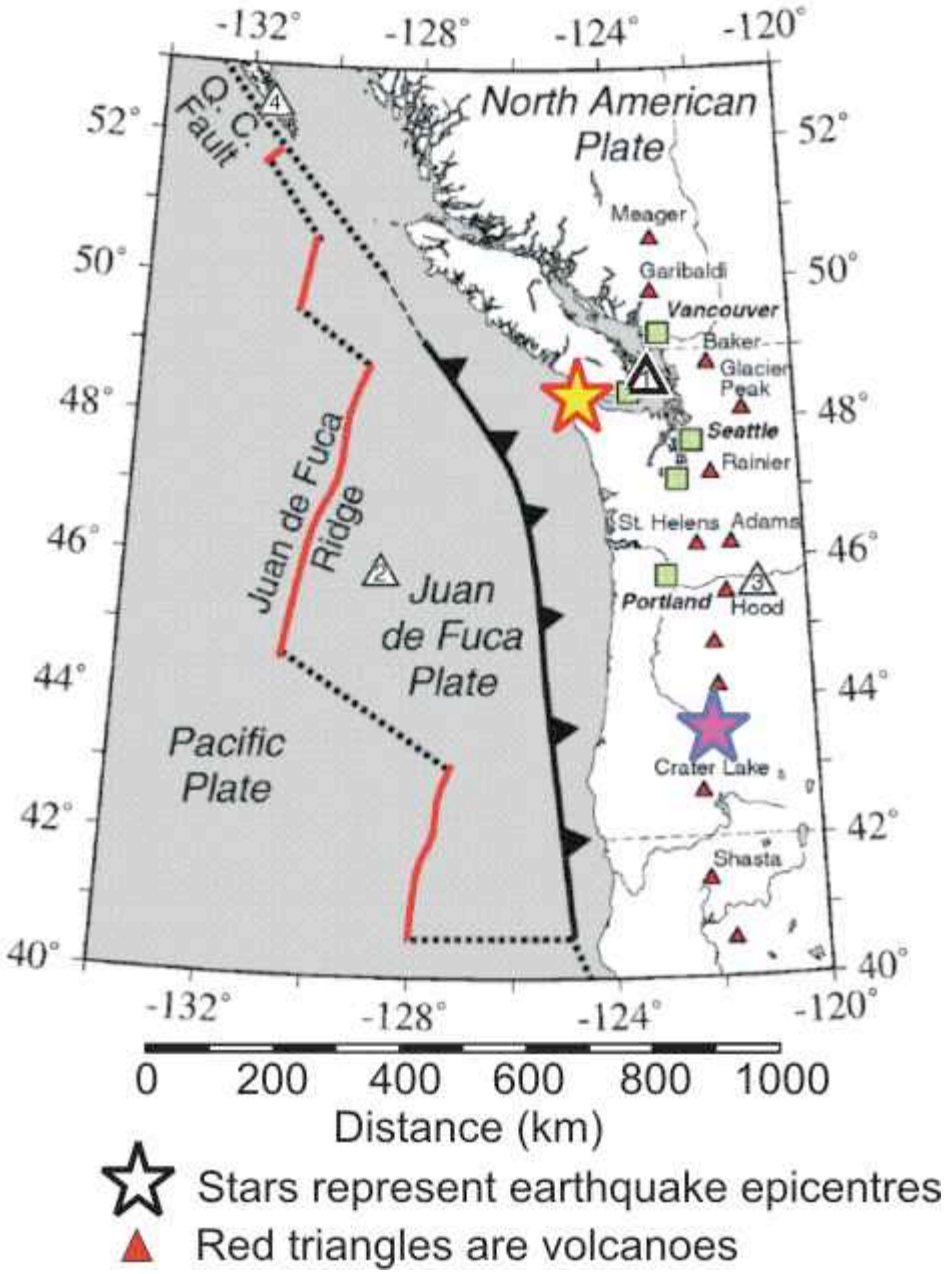
Cities are noted and the red triangles represent the large volcanoes (related to subduction of the oceanic lithosphere).

The next couple of questions will use this figure
Make sure you look at the pdf slides to learn where/why earthquakes occur in subduction zones. Also, the figure in Q11 will give you a cross-sectional view through the area. Ask if you don't understand the question...

NOTE: **More than one** of the following answers may be correct. Answer all those you think are correct (marks are deducted for wrong answers).

There are two *stars* are shown that represent earthquake epicentres.

For the yellow epicentre:



	Student Response	Value	Correct Answer	Feedback
1.	This earthquake's focus must be located in the upper 10 km.			

	Student Response	Value	Correct Answer	Feedback
2.	If this earthquake (red/yellow epicentre) had a very large magnitude, it is quite possible that it would generate a large tsunami	50%	✓	Sure. The quake's epicentre is underwater, and it could be that this earthquake's focus is on the plate interface. If it was a very large earthquake, on the interface, then the plates could release right up to the trench where the subducting plate dips down beneath the overriding plate. That is where large tsunamis are generated.
3.	This earthquake's focus could be located anywhere between 0-700 km depth	-25%		No. It could be located between about 0-65 km depth, but no deeper, certainly not 700 km. The idea of very deep subduction zone earthquakes is that they can occur by metamorphic reactions within the downgoing lithosphere. But here, the top of the subducting plate is only 10-15 km beneath the surface. Below about 65 km it is asthenosphere, below the downgoing plate - so no earthquakes could occur there. Check out the cross-section to visualize this.
4.	The focus would have been located between about 0 (the surface) and ~100 km depth (roughly the bottom of the lithosphere here).		✓	

General Feedback: Other questions in this quiz provide a cross-section through Cascadia. Take a look at that since it will give you a cross-section through the area. Lots in the pdf notes too...

So, this earthquake happens offshore, within or below the continental shelf. The Juan de Fuca system is subducting beneath the continental crust at that point, but it hasn't sunk very deep yet. So, you have the overriding plate being about 10-15 km thick at that point, the oceanic lithosphere extends below that and

because the Juan de Fuca plate is so young (hasn't had a lot of time to cool), it is only about 50 km thick. Then the asthenosphere below that. So, we have a situation where that epicentre could represent an earthquake rupture at a pretty large range of depths. It could be:
i) Within the overriding plate (continental crust) that is being compressed by the collision. So, that would be in the upper ~10-15 km.
ii) On the plate interface (oh oh...). The subduction thrust interface is still shallow and therefore quite cool and brittle. Definitely a depth where it can stick. This is about where the big Sumatra quakes have started to rupture.
iii) The subducting oceanic plate is starting to bend, so, potentially, the quake could be within the downgoing plate. That would mean between the interface (about 10-15 km depth and on down to the bottom of the oceanic lithosphere, about ~65 km, assuming the downgoing plate is about 50 km thick).

Would it be right to say 0-700 km?

No. If the bottom of the subducting plate is about 65 km down there, and there is asthenosphere below that - could there be any earthquakes in the asthenosphere?
No - the asthenosphere is solid, but quite ductile and would never break - it would flow slowly instead.

So, this earthquake focus could represent a possible focus for a huge megathrust release. Check out the figures in the Cascadia Earthquake pdf. There is one that shows a map of the region with the whole locked zone marked out. This epicentre definitely falls in that locked zone. The interface is quite shallow so the temperatures are cool enough that the plates can lock and will rupture elastically - not just ooze past one another slowly. You could also have a tsunami generated as if it was a quake on the interface it could rupture all the way up to the seafloor.

Score: 0.5/2

6.

Again, using the Cascadia map used in the previous 2 questions.

I thought it would be interesting to see how long it actually takes the waves to reach Vancouver from an earthquake.

[To solve this, you'll need the distance scale at the bottom, and typical seismic wave speeds are given in the pdf slides on Seismology/Imaging the Earth.]

Your calculation doesn't have to match exactly because there will be some error in the approximate measurements. Just choose the best answer available.

Question: Two earthquake epicenters are located by the stars in the figure above. Assume that the focus (or initial rupture point) of both of those earthquakes was in the uppermost crust. Match the following pairs:

Statement	Response	Value	Correct Match
For the **yellow epicentre** quake, approximately how long would it take the P-waves to reach Vancouver?	35 seconds	25.0%	35 seconds
For the **yellow epicentre** quake, approximately how long would it take the S-waves to reach Vancouver?	1 minute 0 seconds	25.0%	1 minute 0 seconds
For the **yellow epicentre** quake, approximately how long would it take the surface waves to reach Vancouver?	1 minute 10 seconds	25.0%	1 minute 10 seconds
For the **pink epicentre** quake, approximately how long would it take the surface waves to reach Vancouver?	3 minutes 30 seconds	25.0%	3 minutes 30 seconds

General Feedback: I thought it would be interesting to see how long it would actually take for the waves to reach Vancouver. Note that these are just very rough estimates. To do it properly, you'd need to look at the detailed crustal structure. However, even a rough estimate should be pretty close to the right answer. So to do this, you just need to measure about how far the quake is away from Vancouver - and then use the typical speeds the different waves travel in continental crust. Distance divided by speed gives you the time. For example, driving 100 km at 50 km/hour means it takes you 2 hours...

*Distance: oh, about 220 km
*P-waves in the crust: about 6.0 km/s *S-waves in the crust: about 3.5 km/s
*Surface waves: variable, but about 2.0-2.5 km/s

I approximated the times above, since it would depend on your distance choice. But for example, if you do the calculation using the numbers above:
Time = distance/speed so:
P-wave time 220/6.0 = 36.7 seconds

So, for this earthquake, once you first feel the first bump of the P-waves, you have roughly 25 seconds to wait until the S-waves come in. They would likely be much more powerful than the P-waves and would shake for a while. Then the surface waves would come rolling in about 40 seconds after the first S-waves arrived.

In other words, make sure you wait for a while if you feel a decent sized earthquake - the next phase may still be vibrating toward you (and the later phases are the more damaging ones).

In the M6.8 Tacoma earthquake back in 2001, I felt 2 pulses here in Vancouver - likely the S-wave and surface waves. I didn't feel the P-wave pulse at all.

Think about what would happen if the 'megathrust quake' started there, but zippered the entire subduction zone down to northern California? You know when the first P waves would arrive - but what about the rest of the train of waves?

Would you still feel the different pulses?

Score: 2/2

7.

Ghost forests provide one piece of evidence showing that a very large subduction thrust earthquake occurred a little more than 300 years ago (January 1700). Which of the following statements are true about the Cascadia ghost forests and their formation.
(More than one answer can be true. Points deducted for wrong answers.)

	Student Response	Value	Correct Answer	Feedback
A.	The outer coast in Cascadia is gradually going down.			
B.	The cedar trees were killed by a tsunami that was generated by the thrust earthquake			
C.	The cedar trees were killed by flooding by salt water because the outer coast dropped over 1 m from the earthquake.	50%	✓	This is true. It wasn't the tsunami, it was that the ground dropped on the outer coast. That meant that the valley bottom stands of cedar were now below sea level and the salt water killed them.
D.	The Cascadia "ghost forests" are stands of dead cedar trees that exist down the outer coast of Vancouver Island,	50%	✓	Yes.

	Student Response	Value	Correct Answer	Feedback
	Washington and Oregon. They all died at (very close) to the same time.			
E.	The body waves (P and S waves) produced by the earthquake killed the cedar trees as their resonance frequency is, unfortunately, tuned to surface wave frequencies.			

General Feedback: You should know the evidence that tells us we will, someday, have another "megathrust" subduction earthquake here.

- Current deformation (compression, uplift)
- ghost forests
- tsunami sand layers
- turbidite flows (underwater landslides)
- tsunami records from Japan

How does that evidence compare with what was observed in Sumatra?

Score: 2/2

8.

The amplitude of a tsunami wave increases suddenly when _____.

	Student Response	Value	Correct Answer	Feedback
A.	solar energy amplifies the wave			

	Student Response	Value	Correct Answer	Feedback
	B. an earthquake occurs			
	C. the wave enters shallow water near the shore	100%	✓	
	D. interaction with wind amplifies it			
	E. the wave encounters another tsunami wave			

Score: 1/1

9.

When a Cascadia tsunami approaches southwest British Columbia's shores, some places would be safer from its effect than others. Rank the following locations in order of RISK to life and property if this were to happen.

Statement	Response	Value	Correct Match
Definitely not where you want to be (worst)	Tofino	25.0%	Tofino
Could be pretty bad in places (2nd worst)	Victoria	25.0%	Victoria
Not too bad, but some influence (2nd best)	Vancouver	0.0%	White Rock
No problem	White Rock	0.0%	Vancouver

Score: 1/2

10.

Plates move very slowly and those motions are associated with the vast majority of earthquakes. But earthquakes can result in very very rapid motions along faults. Which of the following statements associated with those observations are correct?

[More than one answer may be correct. Penalty for incorrect answers]

	Student Response	Value	Correct Answer	Feedback

	Student Response	Value	Correct Answer	Feedback
A.	elastic deformation stores up energy that is later released suddenly in an earthquake	50%	✓	
B.	convective mantle flow is generally slow and steady, but it can sometimes move very quickly			
C.	a "great" earthquake could result in rapid offset along a fault of approximately 5-15 metres	50%	✓	Yep! That high!
D.	a "great" earthquake could result in rapid offset along a fault of approximately 5-15 centimetres			
E.	the motion of plates is often accelerated just before an major earthquake			

Score: 1/1

11.

On Venus and Mars, the process (or processes) causing the observed volcanism (current or extinct) is (are):

[multiple answers possible, penalty for wrong answers]

	Student Response	Value	Correct Answer	Feedback
A.	convection related to plumes in the mantle creating 'hotspots'	100%	✓	
B.	convection generated by tidal forcing from their very large moons.			
C.	convection related to plate tectonics			

General Feedback: There was major volcanism on both Venus and Mars. Venus is still active. Recent evidence suggests that Mars is still slightly volcanically active. However, neither have plate tectonics. The volcanism is entirely related to mantle plumes, or hot spots. Neither planet has large moons.

Venus may well have had plate tectonics, but we have no evidence of that although the crustal history only extends to 500-800 million years ago. Plate tectonics may have occurred before that.

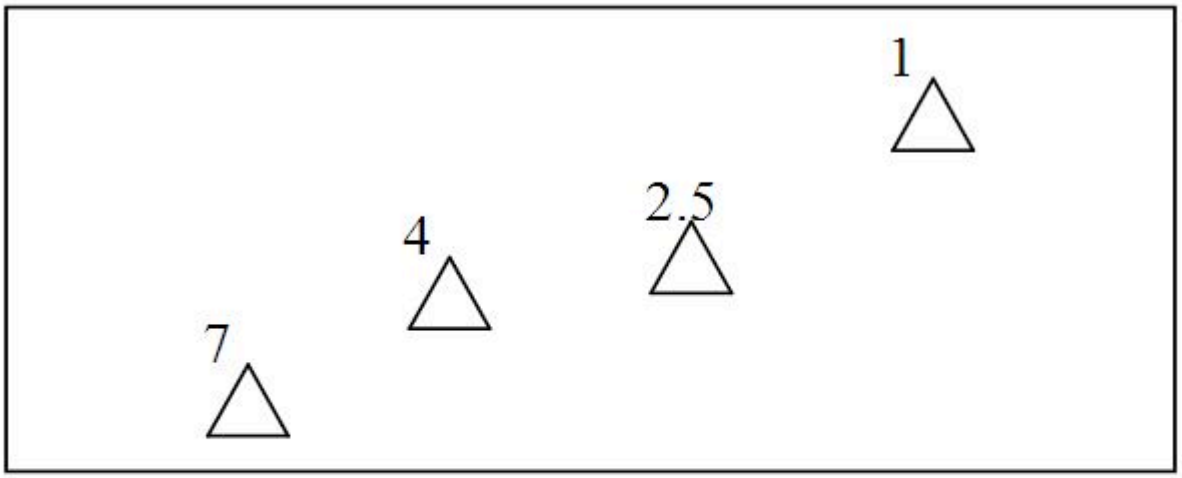
Gravitational forcing can trigger volcanism as is seen on Jupiter's moon Io (incredibly strong tides continually distort the shape of the planet and that processes generates heat).

Score: 1/1

12.

This diagram represents volcanoes on an oceanic plate formed by a mantle plume. The numbers each represent the age (millions of years) of the youngest igneous rocks on each volcano. Perhaps think about the Hawaiian hot spot chain and the age of the rocks on the surface of those volcanoes...

In which direction is the oceanic plate moving?
[Note: North is to the top of the page]



	Student Response	Value	Correct Answer	Feedback
A.	North			
B.	North East			
C.	East			
D.	South East			
E.	South			
F.	South West	100%	☑	
G.	West			
H.	North West			

General Feedback: Remember, the plume location is (relatively) stationary, but the plate moves on top, carrying the older piles of volcanic rock away...

Score: 1/1

13.

You are traveling in Australia and you get a bit lost when tracking goannas in the outback. You need to get back to camp for your didgeridoo lesson. Since you don't know the songlines to lead you back, you are fortunate to have a compass in your pocket. You have a map and getting your bearings is pretty easy. whew.

However, you realize that you have a special compass (these do exist - geologists/geophysicsists use them) that can measure the dip or inclination of the magnetic field. Out of curiosity, you check what the dip is in central Australia. You find:

[To answer this, check out the difference between inclination and declination and what the shape of the field is. No need to look up an answer - you can just figure it out knowing the shape and current orientation of the Earth's field. Remember, compass needle aligns with the field - not only horizontally, but in 3-D.]

	Student Response	Value	Correct Answer	Feedback
A.	dipping downward, into the ground at about 40 degrees			
B.	pretty much vertical (upward)			
C.	dipping upward, out of the ground at about 40 degrees	100%	☑	
D.	almost horizontal			

General Feedback: See some of the images in the first geomag pdf file that talk about dip (or inclination) and declination. Remember, the dipole field is a 3d thing. We have a magnetic north pole where all the field lines go down into. We also have a magnetic south pole where all the magnetic field lines emerge... They're all backwards down under. Or, is it the other way around?

Which way would the compass dip at the magnetic north pole? At the magnetic south pole? At the magnetic equator? So... Argentina is well into the southern hemisphere so that should let you make a pretty good guess. But you can check on an inclination field map or use the NOAA geomagnetic field 'calculator'. See the 1st geomag pdf file - there are some good graphics for this (slides 6-9)

Score: 1/1

14.

Remanent magnetization of the oceanic crust forms anomalous bands (normal and reversed) that are *widest* where:

	Student Response	Value	Correct Answer	Feedback
A.	continents are joined to form supercontinents.			
B.	sea-floor spreading rates are relatively rapid.	100%	✓	Yes, this would cause the bands to be wider because more oceanic crust would be produced for any given polarity period. More crust produced, the longer the band.
C.	sea-floor spreading rates are relatively slow.			
D.	the crust is closer to the magnetic north pole.			
E.	more ferromagnetic material is incorporated into the oceanic crust			

Score: 1/1

15.

Using the Kermadec xsection sketch in the question above (and the Cascadia information in the pdfs), please answer the following question:

The Cascadia and Kermadec subductions zones have similarities and differences. Which of the following answers are true *(more than one may be correct - penalties for wrong answers)*.

	Student Response	Value	Correct Answer	Feedback
A.	The crustal composition	100%	✓	Island arc - more mafic than continental crust. Typically very mafic when the arc is

	Student Response	Value	Correct Answer	Feedback
	of the Kermadec Islands should be more mafic, on average, than that in the Cascade volcanic belt (i.e., here near Vancouver).			young, becoming more intermediate as the overriding crust becomes more and more evolved. A place like Japan is a very evolved island arc and while more intermediate than a major continent, it is getting closer.
	B. The crustal composition of the Kermadec Islands should be more felsic, on average, than that in the Cascade volcanic belt (i.e., here near Vancouver).			
	C. The depth where melting starts is much shallower in the Kermadec arc than in the Cascade arc. (melting is shown by the rising grey blobs in the	0%		Typically melting starts at roughly 100 km depth in all subduction zones. There is some variability due to the temperature (related to age) of the subducting plate and how fast it is subducting.

	Student Response	Value	Correct Answer	Feedback
	figure).			
D.	The Kermadec volcanism is created by a hot spot plume while that isn't the case in Cascadia.			

General Feedback: Island arc - more mafic than continental crust. Typically very mafic when the arc is young, becoming more intermediate as the overriding crust becomes more and more evolved. A place like Japan is a very evolved island arc and while more intermediate than a major continent, it is getting closer.

Typically melting starts at about 100 km depth in all subduction zones. There is some variability due to the temperature (related to age) of the subducting plate and how fast it is subducting. If you had a very cold, fast-moving plate - do you think melting would start shallower or deeper?

Score: 1/1

16.

Using the same figure for the Kermadec quake above, which of the following statements below are **correct**?

[more than one answer is possible, penalty for wrong answers]

	Student Response	Value	Correct Answer	Feedback
A.	The composition of the magma formed just above the subducting plate (the blobs rising near location M on the Kermadec xsection) is			

	Student Response	Value	Correct Answer	Feedback
	the same as the rock where the M is.			
B.	If an earthquake occurred at location 9, it would most likely be a compressional rupture, not a tensional rupture. (You can decide between compression and tension by bending something - perhaps your pen)	50%	✓	compressional on the inside of the bend. At location 1 it would be tensional, although there is also compression there from the collision. So more complicated...
C.	Assume an earthquake occurs with its focus at location #2. No tsunami was reported. This means that the rupture did not break the seafloor at the trench or that the slip was very small.	50%	✓	Yes. You can have earthquakes on the plate interface and they don't need to rupture all the way up to the trench.
D.	The oceanic crust below the dashed line of location 4 has less water in it than the			

Student Response	Value	Correct Answer	Feedback
oceanic crust below the dashed line of location 5.			

General Feedback: Magma near M: Composition of partial melt is different from the source rock. In this case, water triggers the melting in the asthenosphere above the subducting plate. The magma formed is a partial melt of that mantle rock. So, a mafic melt is formed by partially melting the ultramafic mantle rock.

Tsunami: You need the rupture to break the seafloor (at the trench) to cause a typical quake-caused tsunami. Not all interface ruptures propagate all the way up to the trench.

The oceanic crust is saturated with water initially and it loses it when the pressure/temperature is high enough (a combination of pressure and metamorphic changes). It happens at shallower depths, but a last major pulse of water is released by about 100 km depth - that triggers the partial melting that forms mafic magma and results in formation of the volcanic arc above.

Location 9: If you try bending something, you'll see that it is 'stretched' on the outside of the bend and 'compressed' on the inside of the bend. Same with lithosphere as it bends downward when it subducts. At location 1 it would be tensional, although there is also compression there from the collision. So more complicated...

Score: 2/2

17.

Plate tectonics keeps the planet's 'solid' surface in constant, gradual change. Processes such as ridgecrests, subduction, and collisions all influence the surface of the Earth as well as the 'age' of the rocks on the surface. (Consider the 'age' of a rock to be when an igneous rock formed).

Which of the following statements are **true**. (Mark any answer that is correct).

Student Response	Value	Correct Answer	Feedback
A. Continents have remained largely intact since they were originally formed during the iron catastrophe			

	Student Response	Value	Correct Answer	Feedback
	B. Rifting is an important process in breaking up continents (and supercontinents).		☑	
	C. Continents are generally "younger" near their edges as that is where accretion and subduction volcanism can occur.	34%	☑	Yes, that's true. You can have hotspot or plume volcanism in the core areas of continents, but most of the action (accretion and magmatism) occurs along the active plate boundaries - on the edges.
	D. Compared to the oceanic crust, structure of the continental crust is very simple			
	E. Continental structure can be very complex due to deformation, volcanism, and accretion	33%	☑	

Score: 1.34/2

18.

Match the planetary body on the left column to the BEST description of its surface age.
Ga = Billion years

Statement	Response	Value	Correct Match
Moon	age of most of the surface is approximately 4 Ga	25.0%	age of most of the surface is approximately 4 Ga
Mars	age of most of the surface is approximately 4 Ga but there has been ongoing volcanism that may still be active	25.0%	age of most of the surface is approximately 4 Ga but there has been ongoing volcanism that may still be active
Venus	surface is relatively young (1 Ga or less)	25.0%	surface is relatively young (1 Ga or less)

Statement	Response	Value	Correct Match
Mercury	age of most of the surface is approximately 4 Ga	25.0%	age of most of the surface is approximately 4 Ga

General Feedback: A small portion of the moon is younger (~3 billion years old) - those are the 'Mare' impact basins formed by large impacts and then upwelling of mafic magma from the Moon's interior. The majority of the Moon is the highland felsic rock.

Score: 2/2

19.

Match the property on the left to the correct planet(s).

Obviously, this is not one-to-one matching...

Statement	Response	Value	Correct Match
Is home to massive volcanic complexes (active or extinct)	Venus and Mars	14.28%	Venus and Mars
Has a strongly magnetized crust	Mars	14.28%	Mars
Has been entirely resurfaced by volcanic activity	Venus	14.28%	Venus
Is currently undergoing stagnant lid mantle convection	Venus and Mars	14.28%	Venus and Mars
Shows evidence of liquid water flowing on its surface in the past	Mars	14.28%	Mars
Does not have any impact basins comparable in size to the large basins on the nearside of the Moon	Venus	14.28%	Venus
Has an unusually small core	Moon	14.32%	Moon

Score: 3.5/3.5

20.

What is missing (or at least is present in far smaller quantities/proportions) from the composition of Venus that is present on Earth?

	Student Response	Value	Correct Answer	Feedback
A.	sulphur dioxide (SO2)			
B.	Silica (SiO2)			

	Student Response	Value	Correct Answer	Feedback
C.	water (H2O)	100%	✓	
D.	carbon dioxide (CO2)			
E.	graphite (C)			

General Feedback: The key here is that Venus has no water (or very very very little) left. Not only in the atmosphere but also in the crust/mantle. Very different that Earth. They both should have started with similar amounts but Venus has lost it's water. This has major effects in terms of plate tectonics (or the lack thereof) on Venus.

Score: 1/1

21.

You are going over the observations made by a probe orbiting another planet in our solar system. Which of the following would be clues that a planet's magnetic field is not simply due to magnetized rocks, but is currently actively generated within the planet (similar to on Earth)?

Multiple answers possible; penalty for incorrect answers

	Student Response	Value	Correct Answer	Feedback
A.	The solar wind is being strongly deflected around the planet.	25%	✓	Yes, an active magnetic dipole pretty much has to be present. Magnetized rocks near at/near the crustal surface would not produce a strong enough field.
B.	The planet has a strong dipole magnetic field.	25%	✓	
C.	A large mountain is associated with a			

	Student Response	Value	Correct Answer	Feedback
	region of enhanced magnetic field.			
D.	Band or stripes of crustal rock with alternating magnetic polarity are observed.	-40%		It suggests that there WAS a reversing field AND plate motions. However, but it doesn't mean the 'dynamo' is still active.
E.	The field changes noticeably over the time the probe was orbiting the planet.	25%	✓	Yes. It is possible for magnetized rocks to have their magnetization altered. However, those processes tend to be very local and slow.
F.	Aurora - (rings of northern and southern lights near the poles)		✓	

Score: 0.7/2

22.

The computer wakes you from hibernation because it has put the spaceship into orbit at your destination - a terrestrial planet around another star.
You yawn, stretch, and grab a coffee.

Quickly scanning through the data, you are happy to see the planet has active plate tectonics.

Which of the following observations were convincing indicators that plate tectonics was active?

[multiple answers possible]

	Student Response	Value	Correct Answer	Feedback
1.	Relatively young crust is present - there are few impact craters.			
2.	long, deep valleys hundreds or even thousands of kilometers long.	50%	✓	subduction trenches.
3.	chains of conical mountains (likely volcanoes) that are active (hot) only at one end of the chain.	0%		Sounds like a hotspot chain of volcanoes - but you can get that if you have a single plate moving over a mantle plume below. Mars and Venus have plume volcanism. So... it doesn't mean plate tectonics is present...
4.	long mountain belts hundreds or even thousands of kilometers long.	50%	✓	likely formed by plate collision and/or subduction - could also be rift zones/ridges depending on their structure

Score: 2/2

23.

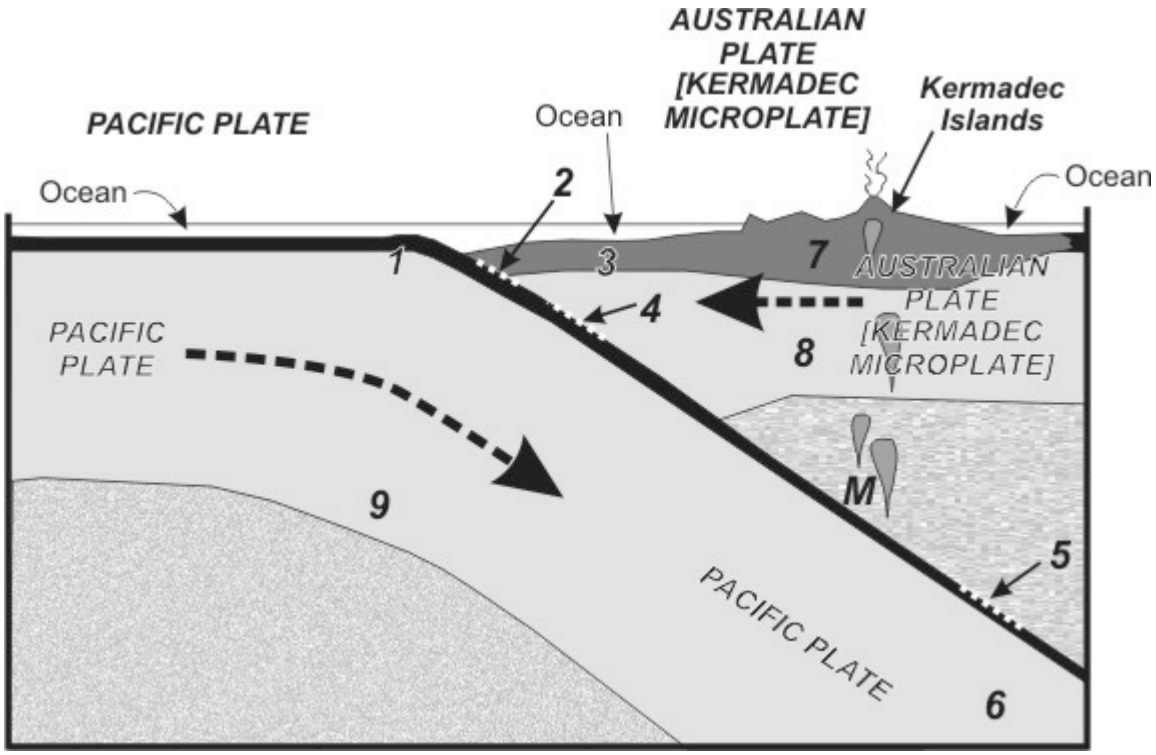
On October 10, there was a small earthquake in the Kermadec Islands - a chain of islands extending to the north-northeast from New Zealand. It was a Mw 4.3. Take a look at the USGS Earthquake page on it: Kermadec Islands, NZ
Also, check out the various maps and information in the different tabs (I like the Historic

Seismicity maps).

The situation there is that the Pacific Plate (produced far to the east at the East Pacific Rise) is subducting down to the west between the eastern edge of the Australian Plate. That is a complex area that is sometimes described in terms of smaller 'microplates' - in this case the Kermadec microplate.

You'll see the cross section I've attached is pretty similar to the one for the Cascadia questions above. (note the orientation.... it is looking from the North (west is on the left side, east is on the right side) - you'll see what I mean if you compare the cartoon cross-section with the Historic Seismicity figure on the USGS website.

From looking at the information on the website (location, depth, etc., which of the numbers in the image is the best choice for the focus of the earthquake?



	Student Response	Value	Correct Answer	Feedback
A.	1			
B.	2			
C.	3			
D.	4	0%		
E.	5			
F.	6		✅	
G.	7			

	Student Response	Value	Correct Answer	Feedback
H.	8			

General Feedback: You can see from the USGS info that the focus was located ~77 km down. There are 3 regions that earthquakes can occur in within subduction zones. The only one that can be that deep is within the downgoing plate.

Score: 0/1

24.

What are the two most abundant elements in the universe?

	Student Response	Value	Correct Answer	Feedback
A.	Hydrogen and Iron			
B.	Oxygen and Hydrogen			
C.	Hydrogen and Silicon			
D.	Helium and Hydrogen	100%	✓	The vast majority of the atoms in the universe (and in our solar system) are H and He. In our solar system these are concentrated in the Sun and in the giant gas planets.
E.	Carbon and oxygen			

Score: 1/1

25.

Once Earth formation had stabilized and light elements were lost from the atmosphere, the Earth's atmosphere developed by volcanic outgassing and contributions from comets being accreted. What are thought to have been the four major components to the Earth's atmosphere in this early phase (~4 billion years ago)?

	Student Response	Value	Correct Answer	Feedback
A.	SO2 (sulphur dioxide)	25%	✓	

	Student Response	Value	Correct Answer	Feedback
B.	NH3 (ammonia)	15%	✓	
C.	CO2 (carbon dioxide)	30%	✓	
D.	H20 (water!)	30%	✓	
E.	O2 (oxygen)			
F.	N2 (nitrogen)			

Score: 2/2

26.

Which of the following processes were important in modifying the Earth's atmosphere from its primordial composition to its current state?
Note: There may be multiple correct answers; wrong answers are penalized.

	Student Response	Value	Correct Answer	Feedback
A.	production of nitrogen by the breakdown of ammonia (NH_3) by UV radiation	25%	✓	Yes. And the hydrogen that was liberated just escapes to space. Earth's gravitational field isn't strong enough to hold hydrogen (it is too small/light).
B.	removal of CO_2 by erosion of rock on Earth's surface	25%	✓	Erosion of silicate minerals (some types of rock are better than others) combined with water pulls CO_2 from the atmosphere and locks it up in different types of minerals. Again, sequestering it for very long periods of time from the atmosphere/ocean system.
C.	removal of CO_2 by formation of carbon-rich rocks (carbonates) in the	25%	✓	Yes, the oceans themselves are a large "sink" for CO_2 in that they absorb far more CO_2 than exists in the atmosphere. However, that carbon is removed from the atmosphere/ocean system for very long periods of time by conversion to carbonate rock.

	Student Response	Value	Correct Answer	Feedback
	oceans			
D.	removal of water vapour by rain, snow, sleet, etc. to form oceans, lakes, and other surface water bodies		☑	
E.	breakdown of ozone by UV radiation, producing our current oxygen-rich atmosphere			

Score: 0.75/1

27.

Our early atmosphere was formed by volcanic outgassing with some contribution from comets. However, over time it changed to the composition we now happily breath in. Our atmosphere is quite different from those of the other planets and moons because we have a substantial percentage of oxygen, O_2.

Match the questions and answers below related to the development of oxygen. Recall: Ma = million years ago, Ga = billion years ago.

Statement	Response	Value	Correct Match
What process generated free oxygen?	UV radiation breaking apart ozone, O_3	0.0%	photosynthetic life
When did O_2 begin to be a substantial or easily detectable (~1%) component in the atmosphere?	2.0 Ga (or 2000 Ma)	25.0%	2.0 Ga (or 2000 Ma)
When did O_2 levels reach their present levels?	0.3 Ga (or 300 Ma)	25.0%	0.3 Ga (or 300 Ma)

Statement	Response	Value	Correct Match
What is the present concentration of O_2 in the atmosphere?	21%	25.0%	21%

General Feedback: Earth's biology/ecosystem is a major component of the physical/chemical systems. Biology has controlled the development of our atmosphere.

In the notes you'll see that the oldest dates that atmospheric oxygen has been detected was about 2.5Ga (some hints of older ages though). But it took until 2.0 Ga for oxygen levels to very slowly rise to about 1%.

Score: 1.5/2

28.

The Earth's atmosphere consists of many different gases. Of the following 5 gases, rank them in order of their current abundance in the Earth's atmosphere.

Note: the '4th most abundant' gas on this list is not necessarily the 4th most abundant gas overall in Earth's atmosphere - just the 4th most abundant of the 5 gases chosen for this comparison.

Statement	Response	Value	Correct Match
Most abundant (#1)	Nitrogen	20.0%	Nitrogen
Second-most abundant (#2)	Oxygen	20.0%	Oxygen
Third-most abundant (#3)	Argon	20.0%	Argon
Fourth-most abundant (#4)	CO2	20.0%	CO2
Least abundant (#5)	Ozone	20.0%	Ozone

Score: 1.5/1.5

29.

Which of the following are TRUE statements relating to the greenhouse effect?

There may be multiple correct answers; wrong answers are penalized.

	Student Response	Value	Correct Answer	Feedback
A.	Mars has a much stronger greenhouse effect than Earth's because its			

	Student Response	Value	Correct Answer	Feedback
	atmosphere is almost entirely CO2.			
B.	The primary attribute of a greenhouse gas is that it absorbs incoming radiation from the Sun (and not radiation from the Earth).	-33%		
C.	A planet moves toward stability or balance in terms of heat in from the Sun versus heat radiated from the planet.	33.333%	✓	Yes. Things are rarely perfectly stable - but if it isn't - the planet would continue to warm or continue to cool. That isn't observed.
D.	Water vapor is a greenhouse gas.	33.333%	✓	
E.	The Earth emits infrared radiation (heat).	33.333%	✓	

Score: 1.34/2

30.

Which of the following characteristics apply to the climate change that is currently occurring?
Note: There may be multiple correct answers; wrong answers are penalized

	Student Response	Value	Correct Answer	Feedback
	A. Warming of the Earth in the last 30 years correlates with changes in Solar luminosity.			
☑	B. The current global average temperature is higher than any seen in the geologic record.	-30%		No, it has been warmer in the past... the key is how FAST it is warming right now.
	C. If anthropogenic emissions of greenhouse gasses stabilize, the climate will also stabilize in less than 5 years afterwards.			
☑	D. Recent changes in Earth's climate correlate with the rise of atmospheric CO_2 stemming from human activities. The physics is consistent with that correlation.	50%	✓	

	Student Response	Value	Correct Answer	Feedback
E.	Climate is changing (average global warming) on a shorter timescale (i.e., more rapidly) than one typically sees in the geologic record (excluding catastrophic events such as impacts).	50%	✓	

Score: 1.4/2

31.

What would the average Earth temperature be WITHOUT the greenhouse effect? (It is approximately 15 °C WITH the greenhouse effect).

	Student Response	Value	Correct Answer	Feedback
A.	-87 °C			
B.	-63 °C		✓	
C.	-16 °C	100%	✓	
D.	0 °C			
E.	5 °C			

Score: 1/1

32.

Which of the following are greenhouse gasses in the Earth's atmosphere?
Note: There may be multiple correct answers; wrong answers are penalized.

	Student Response	Value	Correct Answer	Feedback
A.	CFCs (chlorofluorocarbons)	20%	✓	Yes. Small percentage, but very effective as a greenhouse gas.

	Student Response	Value	Correct Answer	Feedback
B.	N_2O (nitrous oxide)	20%	✓	Yup.
C.	CH_4 (methane)	20%	✓	
D.	H_2O (water vapour)	20%	✓	
E.	CO_2 (carbon dioxide)	20%	✓	
F.	O_2 (oxygen)	0%		
G.	N_2 (nitrogen)			

General Feedback: CO2 is the one that we hear the most about.
However, there are others that are less common but are actually much more efficient greenhouse gases. Therefore, they need to be added in.
e.g., methane, CFCs, nitrous oxide, tropospheric ozone (which is different from the ozone layer, up in the stratosphere).

Also, water is a very effective greenhouse gas. As you warm the world, more water evaporates - therefore the effect of water must be considered in the models! In addition, clouds play an important role (see discussion).

See slide 10 in the second climate pdf file.

Score: 2/2

33.

Until humans really started modifying the planet (especially in the last 150 years with fossil fuel burning) there were three main factors that "forced" the Earth's climate:

- changes in the Sun's output (irradiance)
- changes in the Earth's orbital patterns around the Sun
- changes related to tectonics and volcanism

Milankovitch, a Croatian geophysicist, observed how the orbital variations of the Earth produced cycles with periods that closely matched the Earth's Ice Age cycles that have occurred over the last 2.5 My. Related to those orbital variations, which of the following statements are CORRECT?

Note: There may be multiple correct answers; wrong answers are penalized.

	Student Response	Value	Correct Answer	Feedback
A.	The Earth's rotational axis is tilted with	40%	✓	Yes. Greater axial tilt means there is a bigger shift between winter and summer. However, the effect is actually the reverse

	Student Response	Value	Correct Answer	Feedback
	respect to the plane of its orbit around the Sun. That tilt wobbles back and forth between approximately 22.1 and 24.5 degrees.			as what you'd think. Rather than colder winters starting ice ages, the trick is to have cooler summers (where not as much ice is melted!). This cycle takes approximately 41,000y
B.	The Earth's rotational axis precesses (rotates) slowly around, affecting how the northern hemisphere tilts toward or away from the Sun.	30%	✓	Yes. So if the Earth's rotational axis was ideally "vertical" - aligned exactly the same as the Sun's, it has a tilt that varies (see the other answer). But in addition, it rotates or precesses around that "ideal axis". So that influences how the Earth's hemispheres tilt toward/away from the Sun. The main controls are interactions between the Moon's and the Sun's gravity. This has a cycle of roughly 26,000y.
C.	The orbital variations produce very large changes in seasonal temperature. These temperature shifts override anything that happens in the rest of the climate system.			
D.	The secular variation of the dipole axis slowly varies, controlled by convection changes in			

	Student Response	Value	Correct Answer	Feedback
	the outer core. It wobbles but the tilt averages 11.5 degrees.			
E.	The ellipticity or eccentricity of the Earth's orbit around the Sun changes gradually. It becomes more circular and then more elliptical.	30%	✓	Yup. That wobble is primarily caused by interactions with the gravitational fields of Jupiter and Saturn slightly disrupting/tugging on Earth's orbit. It is quite a complex interaction, and there are several periods involved, but the main cycle is about 100,000 years. It can control the relative length of the seasons.

Score: 2/2

34.

Match the description or scenario in the left column with the type of feedback.

Statement	Response	Value	Correct Match
a response that tends to amplify the change in forcing	positive feedback	20.0%	positive feedback
a response that tends to suppress the change in forcing	negative feedback	20.0%	negative feedback
Sea ice reflects a lot of energy back to space, and melts when temperature rises.	negative feedback	0.0%	positive feedback
If you make enough money, you can invest some of it every month. Return on investments increases your income.	positive feedback	20.0%	positive feedback
When prices go up, fewer people buy. When demand decreases, prices go down.	negative feedback	20.0%	negative feedback

Score: 1.6/2

35.

Which of the following reflects the most sunlight (i.e., has the highest albedo)

	Student Response	Value	Correct Answer	Feedback
	A. Desert sand			
	B. Daisies			
	C. Water			
	D. Snow	100%	✓	
	E. Coniferous forests			

General Feedback: Interestingly - perhaps surprisingly, water is the least reflective (has the lowest albedo) of those choices! Something to consider when thinking about melting arctic sea ice...

Score: 1/1

36.

One of the biggest uncertainties in climate models is understanding how clouds will change as the Earth warms and more evaporation creates more clouds. They are very difficult to model for many reasons. In addition, they can both warm or cool the atmosphere depending on what type of cloud they are. Clouds can reflect light, but they can also absorb light, reradiating it as heat.

A warming planet should produce more clouds (more evaporation), but it is challenging to determine the details of the types and locations of the clouds in a warming world.

Match the following according to how clouds behave in our atmosphere.

Statement	Response	Value	Correct Match
low clouds	cool the planet	50.0%	cool the planet
very high clouds	warm the planet	50.0%	warm the planet

General Feedback: I've always thought this was a bit counter-intuitive.

Low clouds have high albedo and reflect sunlight quite efficiently. They are also warm and don't trap long-wavelength light (heat) as well. Therefore, the net effect is one of cooling.

High clouds (thin, high cirrus) are too thin to block much incoming solar energy. They don't have a very high albedo. However, they are quite efficient at reflecting long-wavelength energy (heat) radiated from below. So they act to increase atmospheric temperature

The question is, as global temperatures warm and more water is evaporated, how will the cloud distribution change. It is very difficult to model. Will the clouds help

us? Will they act to slow down the greenhouse warming? Or, will they make things worse? The range of possibilities are modelled - and that is one of the main reasons for the range of uncertainties you see in the climate models. It's very difficult and is a big focus of research (e.g., Dr. Phil Austin in EOS/UBC).

Score: 2/2

37.

Due to the arrangements of the continents, ocean current patterns, etc., models predict that one region of the world will warm much faster than any other. That is being observed. Which region is it?

	Student Response	Value	Correct Answer	Feedback
A.	the Arctic	100%	✓	
B.	Eurasia			
C.	the Antarctic			
D.	North America			
E.	Africa			

Score: 1/1

38.

We know that climate patterns have changed very rapidly in the past. Although the main forcing factors only provide very small, and generally extremely gradual changes, sometimes the response by the climate system is fast. That is a non-linear response and what is often referred to as a 'tipping point'. It does **not** mean that a process has past the 50% mark. Instead it means that the system **switches** into another mode. Changes occur gradually when climate is in one relatively stable pattern until the limit is reached - then whoops - a shift to a different climate mode, perhaps one that is quite stable as well.

One of the mechanisms for that to occur is a change in the ocean current pattern.

Models indicate that a gradual slowdown will occur in the next 100 years and *not* a rapid change. However, it does remain a concern since rapid changes in ocean currents would also mean massive changes in weather patterns, affecting global agriculture.

The following list includes things involved with ocean currents and the North Atlantic Deep Water formation in particular. Which of them are **true** ?

[More than one answer may be correct. Marks deducted for wrong answers.]

Completed

Student Response	Value	Correct Answer	Feedback
A. Evaporation increases the salinity (salt concentration) in the surface sea water in the tropics.	25%	✓	Yup. And when that salty water is carried into the North Atlantic by the Gulf Stream, and the cooled by the very cold arctic winter temperatures, it becomes extremely dense and sinks to the bottom. Convection.
B. Ocean currents are a convection system involving heat, gravity (like mantle convection) and also salinity.		✓	
C. Fresh water is more buoyant (less dense) than salt water. It doesn't want to sink.	25%	✓	Yup. It is the cooling of very dense salty water that is a key driver of our ocean current system. If you put huge amounts of fresh water at the surface (say from melting the sea ice and Greenland ice cap), it won't sink and the current systems will change.
D. Ocean currents carry a great deal of heat energy that not only affects the climate system - it directly affects people/agriculture.	25%	✓	Yes. Weather systems over continents are influenced a great deal by the oceans. Warm ocean waters carried closer to the poles (like the Gulf Stream) have a significant warming effect on northern Europe. In other areas, cool ocean waters have a cooling effect. If you change that rapidly - weather patterns will change rapidly...

General Feedback:

* It is the cooling of very dense salty water that is a key driver of our ocean current system. If you put huge amounts of fresh water at the surface (say from melting the sea ice and Greenland ice cap), it won't sink and the current systems will change.

* Ocean currents are a convection system involving heat, gravity (like mantle convection) and also salinity. When the warm, very salty water is carried into the North Atlantic by the Gulf Stream, and the cooled by the very cold arctic winter temperatures, it becomes extremely dense and sinks to the bottom. Convection.

* Weather systems over continents are influenced a great deal by the oceans. Warm ocean waters carried closer to the poles (like the Gulf Stream) have a significant warming effect on northern Europe. In other areas, cool ocean waters have a cooling effect. If you change that rapidly - weather patterns will change rapidly...