September 1 Lecture Notes: Logistics and a few Plant Communities…

I. Field trip reminders and discussion
Friday Sept 8th (next week!) is La Cumbre Peak field trip.
Saturday Sept 9th (also next week!) is Guadalupe Dunes field trip
Sunday Sept 10th – NO FIELD TRIP (TRIP CANCELLED)

Come prepared to botanize feverishly!

Details:
We will **depart SBCC at 7:30am SHARP for BOTH fieldtrips!!**. ARRIVE NO LATER THAN 7:15am and be ready to leave by 7:25!!
We will return to SBCC at **~3:00-4:00** (field trips sometimes run late…for reasons beyond our control!).
What to bring:

- Appropriate clothing (it will likely be very hot in the afternoon)
- Sun protection (hat, shades, etc.)
- Plenty of water! (at LEAST 1-2 quarts)
- Lunch and snacks
- Field notebook and pencils, eraser
- Plant presses (dune, chaparral, sage scrub, riparian, and montane CF groups!)

II – IV: Plant community overviews for future field trips

II. Sand Dune Plant Communities

Sand: granules of finely divided (i.e., eroded) rock and mineral particles.
(FYI: sand = 0.0626-2mm; gravel = 2-64mm; silt: 0.002-0.0626mm; clay < 0.002mm)

There are many different types of sand. Most sand in temperate (i.e., non-tropical) regions contains high levels (typically 80%+) of quartz, because quartz is common in rock that is weathered to form sand, and because it is more durable than other minerals in rock and thus it takes longer to completely break down into silt or smaller particles. Quartz is a mineral constructed from silica molecules: SiO_2 (for you non-chemistry folks, this is one silicon atom bonded to two oxygen atoms – you don't need to know this…).
(Note that in Santa Barbara, the rock that is weathered to form sand is sandstone – thus it is rock that was formed when sands on an ancient seafloor accumulated and formed sedimentary rock. Thus, our sand is on (at least) its second life as sand!)

Sand on tropical beaches may originate from eroded volcanic rock (in which case the beach is typically a black sand beach), or as is usually the case may be from weathered coral and other calcium carbonate exoskeletons in marine animals (e.g., seashells, sea urchin tests & spines, etc…). Such sand is said to be "biogenic", because it originates from once-living organisms. In the latter case, beach sands are white, and the sand may be formed not by physical erosion but by predatory fish or urchins that ingest and pulverize corals or shells. I had a friend once (really, I did…!) who studied sand dynamics in Hawaii, and he estimated that perhaps most of the sand on Hawaii has passed though the gut of a fish! (Not sure if this is true…but it's a nice story…and he was my friend…).

Sand sources, sinks, and transport along the California coast

On California's coastal beaches, sand originates from erosion of sea cliffs (~10% of total) or inland (terrestrial) sources (~90%) and flows to the coast down creeks and rivers (CDFG 2002). Once at the coast, sand is transported parallel to (i.e., along) the shore by currents in a process known as **longshore transport**. In California, **longshore transport** is predominantly southward (and it is along the entire west coast of North America). Sand may move northward on small scales, and it moves on-off shore on a seasonal basis or in rip-currents. However, the general trend over long time scales is: a) terrestrial origination, followed by; b) southerly longshore transport in ocean currents. This is where our beach sand comes from. Where, ultimately, does all this sand end up (where does it go if not on a beach, or after it leaves a particular beach)? The most important **sinks** are deep submarine canyons, harbor entrances, and coastal dunes.

Rocky headlands and deep submarine canyons divide California's coastline into physically defined cells that do not import or export significant amounts of sand through longshore transport. These are called **beach compartments** or **littoral cells**. In general, the majority of sand grains in a particular cell either remain in that cell or exit through some sink – but they are not transferred alongshore to another cell. Prominent examples of littoral cell boundaries in our area are Pt. Conception, Pt. Mugu and an associated deepwater canyon, Pt. Dume, and the Palos Verdes Peninsula. In each cell, beaches towards the down-current (south or east, in our area…) will receive more total sand than beaches towards the up-current end of the littoral cell (north or west in our area). This is due to longshore transport of sand in that direction, in addition to the fact that more total creeks contribute sand to the longshore process as one moves toward the "down-current" end of a beach compartment. Thus, beaches are often wider near the down-current extent (in our area: southern or eastern) of beach compartments/littoral cells. The Guadalupe Dunes are a sand deposit at the southern extent of a littoral cell. Let's go there!!

Longshore transport: transportation of sediments (e.g., sand) along a coast at an angle to the shoreline. Driven by currents and wave action.

Dune formation, structure, and movement (here, wind-formed, or Aeolian):
(note: we diagrammed these processes in lecture – you should be able to as well for the final exam(s)! You should also be able to define the bolded terms.)

Sand dunes initially form when sand particles are blown by wind across a large and semi-flat surface, and then encounter a 3D object such as a log, tree, rock, etc. As the sand grains encounter the object, some lose their directional momentum and fall back to Earth due to gravity. As grains accumulate, the object becomes covered in sand and the dune begins to form. At some point, the dune itself becomes the 3D object that causes sand grains to lose their momentum. Sand grains continue to accumulate until, if conditions permit, a full dune develops. Sand grains typically move along the surface of the flat beach or dune by "bouncing" or "skipping" across when momentarily suspended in intermittently strong gusts of wind. This phenomenon is known as **saltation** (from the L: salt = leap). Hopefully we won't see *too much* of this on our field trip!

As winds continue to deposit sand on the **windward** side of a dune, the windward side maintains a "gentle" (i.e., not steep) slope and the dune grows taller. Eventually, the top forms a crest because more sand grains are deposited onto the windward side than on the **leeward** side. The leeward side remains at a steep angle until finally it becomes so unstable that the crest fails and sand cascades down the leeward side. For this reason, the leeward side of a dune is referred to as the **slip-face**. Sand cascades down the slip face when steepness of the slip-face exceeds ≈30-34°. This angle (≈**30-34°**) is known as the **angle of repose**.

Fully-formed sand dunes will continue to experience transfer of sand grains from the windward side to the slip-face for two reasons: 1) wind, and 2) avalanching of the crest when the slip-face angle is greater than the angle of repose (≈30-34°). In this manner, the grains can actually cycle from the upper surface of the windward side and/or crest to the bottom side of the slip-face, and over again in a manner that one researcher likens to the tread of a tank or bulldozer (http://science.nasa.gov/science-news/science-at-nasa/2002/06dec_dunes/). Eventually, as sand grains continue to be transferred the entire dune may actually migrate in the direction of the leeward side. How fast can dunes move? Some dunes can move faster than you might think! Individual storms can move dunes many meters in a single day, and the Chinese village of Longbaoshan is bracing for the arrival of a sand dune system that is advancing at ≈20m/year (http://news.bbc.co.uk/2/hi/asia-pacific/778325.stm).

Sand dune: a hill of sand formed by wind (or water).
Aeolian dune: a dune formed by wind (from the Greek god of wind, Aeolus)
Dune field: a large area covered in dunes
Unstabilized dune (aka active dune): a dune that has not been stabilized (e.g., by plants) and can migrate.
Stabilized dune: a dune that is "anchored" in place (typically by plants)
Blowout: area where sand has been removed by wind, often caused by removal of vegetation
Incipient dune: a newly forming "young" dune

Dune zones and ecology:
Coastal strand: ephemeral plant community immediately above the high tide line
Plant diversity and biomass lowest of all plant communities listed here

Foredune: a vegetated dune ridge that runs parallel to a shoreline.
Plants here are pioneer species.
Diversity is low.
Disturbance and salt stress are high
Nutrients are low
Plant adaptations: deep taproots, ability to grow when buried (e.g., *Ammophila arenaria*), succulent (i.e., thick) leaves and/or stems, trichomes, long horizontally growing stems (stabilize sand), sand armor (e.g., *Abronia* spp).

Hind dune: a dune that is inland from the foredune. Compared with foredunes:
Plant diversity here is higher
Biomass is higher
Disturbance and salt stress is lower
Soils are more developed

Slack: the trough between dunes

Wetland: land area saturated with water and supporting one of four characteristic ecosystems: marshes, swamps, bogs, and fens.
Marsh: Wetland plant community dominated by aquatic herbaceous plants, typically at edge of river, estuary, or lake – can be High diversity and very high productivity/biomass
Glade: depression that is close to the water table and therefore characterized by moist soil

<u>IIb Riparian plant communities – more detail in the field</u>

III. Riparian: associated with flowing fresh water (e.g., creeks, rivers, streams). We'll discuss on the field trip.

<u>IV. Chaparral</u>

Chaparral: Dense thickets of short woody plants that are: 4-12 feet (or more) in height, fire resilient, drought tolerant, and have small sclerophyllous leaves.
(The term "chaparral" derives from the Spanish term "chaparro", which means "short".)

- Most widespread plant community in CA
- Covers ~5-9% of the total area of the state (estimates vary by source).
- Key factors (selective pressures) we'll discuss: drought, fire, and soil (to a lesser extent)

Characteristic of **Mediterranean climate:**

- Warm dry summers often with drought conditions, and cool wet winters.
- Five locations on planet Earth have Mediterranean climates: 1) Southern CA/Northern Baja, 2) Mediterranean Europe/Africa, 3) South Africa, 4) Southern and Western Australia, and 5) Chile.
- *(FYI, no need to know for exams: Occur between 30°-45° latitude on the western edge of continents)*

Drought: an extended period of water deficiency in a region. (Droughts are typically described as occurring over multi-year periods, but can occur on time scales of months or even weeks. Thus, it is reasonable to refer to dry & hot summers as drought-like or causing drought.

Chaparral plants have numerous adaptations to minimize heat stress and water loss during the warm, dry Mediterranean summers (or prolonged dry periods of **drought**)

- Deep roots
- Sclerophylls
- Small leaves
- Lightly colored leaves
- Vertical orientation of foliage

Characteristic (generalization)	**Chaparral ("hard chaparral")**	**Coastal sage scrub ("soft chaparral")**
Vegetation height	4-12^{+} feet	3-6 feet
Adaptation to fire	Resilience: Resprouting, reseeding from local sources	Resilience: Reseeding - local or outside sources (no resprouting)
Branches/plants	Woody, forming dense thicket that is often impassable, forming canopy	Mostly herbaceous or subshrubs (some woody shrubs), lower density often passable on foot, no canopy
Leaves	Sclerophyllous (e.g., *Ceanothus*) or thickened and small (e.g., *Adenostoma* [chamise]).	Thin, drought deciduous (*Salvia*, *Artemesia, Acmispon glaber* [deerweed], *Mimulus*), aromatic (e.g. *Salvia*, *Artemesia*)
Roots	Deep	Shallow (utilize fog

Fire is a major disturbance factor in chaparral communities. Nobody is sure how frequent these fires were before humans, but Rundel and Gustafson (2005) estimate that any location in the chaparral likely burned due to lightning fires once every 30-100 years, other estimates range from 30-150+ years (California Chaparral Institute website).

Fire and wind
Most large fires in the Santa Barbara region are driven by high wind events. Two notorious winds are associated with fires in our area, these are **Santa Ana** winds and **Sundowner** winds. These two weather phenomena have important similarities and differences. Both are katabatic, and the air masses warm due to adiabatic heating.

Katabatic wind: A wind that flows downhill due to gravity. Usually, katabatic winds originate when a relatively cool (and high density) air mass begins to flow downslope because it is denser than the air below it (say, along the slope of a mountain). (from Gr: *katabaticos* = "going downhill").

> **Heat** (a simplified definition useful to us): the kinetic energy (motion) of, and consequent collisions among, particles or molecules in an object or system (temperature is a measure of this).

Adiabatic heating: heating of a gas caused by increased pressure of the gas
Adiabatic cooling: cooling of a gas caused by decreased pressure of a gas

The key to understanding adiabatic heating and cooling is to remember that heat (and our measurement of it, namely temperature) is caused by the collisions of molecules in a gas (or any object).

So, imagine we have two volumes of an identical gas. If we rapidly decrease the volume of one (while maintaining the same number of molecules), then we can increase its temperature. Recall the piston from class – we decreased the volume (and thus increased the pressure) in the piston by compressing the gas molecules into a smaller volume.

The physics of this is explained by the Ideal Gas Law (PV=nRT), which we might or might not have discussed in class, and which is explained below. I won't test you on this – but you might find it useful for understanding adiabatic heating/cooling.

We are now ready to discuss Santa Ana and Sundowner winds.

Santa Ana Winds
Santa Ana Winds originate when high air pressure develops in the Mojave Desert/Great Basin region of North America. Santa Ana Winds can occur any time of year, but they are most common in fall and winter. During these seasons, air over the continent is cooler than air near the coast. This cool air is dense, and it flows downward due to gravity, then forms a region of high pressure when it reaches the Earth's surface.

As the relatively cool, high pressure air flows towards the coast, it must pass over the transverse and peninsular mountain ranges of California. As it does, it may cool slightly more.

However, after the air has passed over these high elevation mountains, it begins to flow downhill due to gravity (it is now **katabatic**!) because it is denser than the relatively warm coastal air (which might actually feel cool to us – depending upon the day!).

As the air mass flows downhill, it is lower in the atmosphere and thus the atmosphere exerts greater pressure on the air mass. Don't forget – air has mass, and under gravity, it has weight!! As the air mass experiences the increase in pressure, one or both of two things can happen: 1) the volume can decrease (the air is compressed), or 2) temperature can increase. In the case of the Santa Ana winds – both happen, but we feel the temperature increase most noticeably. This is due to the ideal gas law (PV=nRT), which is explained below! In the case of dry air in the atmosphere, it increases ~3.5-5.0°F for every 1000ft of altitude lost (assuming the change in altitude/elevation is instantaneous – which isn't quite realistic…but the point remains valid!).

Santa Ana winds are typically very warm by the time they reach us in coastal Santa Barbara because they have experienced significant loss of altitude and thus adiabatic heating. They are like the air in the piston that, in class, caused the piece of paper to catch on fire – remember that?!

These winds get their name from Santa Ana canyon in southern California. This is a region where the winds are strong, but they blow strongly across southern California…and so why Santa Ana won the "naming contest" is unclear…and unfair!

Sundowner winds

Sundowner winds are like Santa Ana winds in that they are katabatic winds that experience adiabatic heating. They are different in that they are much shorter distance phenomena. They originate in the Santa Ynez Valley and blow across the SB coast. Their name derives from the fact that they tend to blow in the evenings and at night. They are a Santa Barbara phenomenon.

Both winds "drive" fire across landscapes by delivering oxygen and blowing flames horizontally, and they also exacerbate conditions by desiccating (drying out) vegetation because they are dry and hot.

The physics of adiabatic heating/cooling (you do NOT need to know this):

For those of you familiar with the Ideal Gas Law, adiabatic heating and cooling should feel very comfortable *(this material will not appear on the final exam, this is FYI)*:

The Ideal Gas Law: $PV = nRT$

Where, for a gas in a system:

- P = pressure of a gas
- V = volume of a gas
- n = number of molecules of the gas (for a closed or sealed system, a fixed number)
- R = a coefficient (here, and always, a fixed number!!)
- T = temperature of the gas

For a gas in closed (i.e., sealed) system (which, for convenience, we assume our winds to be…), the number of molecules of that gas does not change (no gas molecules are added or removed). Under such conditions, when one of variables P, V, or T changes, our equation (PV=nRT) indicates that one (or more) of the others must also change. For example, according to PV=nRT, as the pressure (P) exerted on a gas increases, either the volume (V) will decrease or the temperature (T) will increase, or both will happen. Remember: The value of "PV" must remain equal to the "nRT"!

Plants and plant communities adapt to fire by becoming **fire resistant** or **fire resilient** (or both).

Resistant: not easily or not at all affected by an outside force (fire e.g., redwoods, oak trees)
Resilient: affected by outside force, but recovering quickly (fire e.g., chaparral, coastal sage scrub)

Chaparral plant communities are resilient to fire. Intense fires typically cause removal of the entire community at a particular site. Post-fire regrowth of chaparral dominant species occurs via two mechanisms: 1) resprouting of damaged plants, and/or; 2) growth from seed.

Obligate sprouters: Plants whose seeds do not survive high fire temps., but have burls/lignotubers for resprouting.
Obligate seeders: Plants that do NOT resprout, thus reproduce and repopulate via seed after fire.
Facultative resprouters: Plants that can resprout AND grow from seed after fire

<u>Resprouting from below-ground tissues called lignotubers:</u>
Lignotuber: A woody swelling of the root crown, which contains buds, and from which new shoots can grow. Lignotubers are often referred to as a basal burl – this is technically incorrect. Lignotubers are developmentally programmed structures that the plant constructs based on information coded in its DNA. Burls are different – see below.

Burl: a deformed woody growth in trees, not a normal developmental feature, but caused by an environmental "insult" such as infection or physical injury that disrupts the normally concentric growth of the vascular cambium (compare to lignotuber).. Burls often contain dormant buds, and may be either above or below ground.

<u>Germination of seeds that are buried in the soil.</u>
Chaparral plants produce large numbers of seeds that can accumulate in the soil **seed bank** and remain dormant over long periods of time. In order to germinate, their seed coat must be compromised or scarified:

Seed Bank: accumulation of seeds in soil, awaiting some cue to germinate and grow
Scarification: cutting or softening of the seed coat to hasten germination. Typically via heat, physical abrasion, or chemicals.

Heat-induced scarification:
Wildfires can burn through chaparral communities at extremely high temps: often 800-1200 F. Seeds exposed to these temperatures are destroyed, but seeds buried beneath the surface are exposed to much lower temps of ~200-300 F. (Wildfires move very fast and seeds need not be buried too deep to be insulated from lethal temps). Such temps are in the range that scarifies *Ceanothus megacarpus* (and other species) seeds and breaks their dormancy – and they sprout at an opportune time when competition is eliminated.

Smoke-stimulated germination:
Plants such as the fire followers *Emmenanthe penduliflora* (whispering bells) and *Nicotiana attenuata* have seeds that germinate upon exposure to chemicals in burned vegetation – a "clever" adaptation to germinating after fire!

Thought question: what is the benefit of germinating after fire? Can you replay in your mind the sequence by which natural selection would give rise to this adaptation? We'll discuss this around a campfire (how appropriate…!).

After fires have burned through chaparral plant communities, different species may cover the landscape for a few years while the dominant species are re-establishing. A general term for such species is **pioneer species**, and when they pioneer recently burned areas they are known as **fire followers**.

Examples of **fire followers** from lecture include:
Phacelia spp.
Papaver californicum (fire poppy)
Lotus scoparius/*Acmispon glaber* (deerweed)
Emmenanthe penduliflora (whispering bells)

Deerweed is in the Fabaceae and like other legumes it is a nitrogen-fixing plant (recall the nodules in the roots of legumes? Recall why organisms need nitrogen?). It therefore might play an important role in recovery of fire-afflicted chaparral communities.

Fire followers are more nutritious for game animals than mature chaparral indicator species such as chamise and *Ceanothus*, and such plants are easier to hunt in as well. There is very good evidence that Chumash peoples intentionally burned areas to manage vegetation types to improve hunting. Chumash also seeded *Nicotiana* spp. into burned areas (these plants have smoke-induced germination), whereas *Ceanothus megacarpus* has heat-induced scarification.

Fire followers and <u>ecological succession</u> in chaparral and coastal sage scrub
Fire followers are common in chaparral and coastal sage scrub. Their appearance after a fire, and their ultimate displacement by dominant species of the climax community, is an example of ecological succession.

Ecological succession: Replacement of populations (i.e., species) in an area through a regular sequence to a stable state/equilibrium. Follows a disturbance.

Disturbance: A temporary change in environmental conditions that causes a drastic change in a plant community or ecosystem (e.g., fire, flood, severe wind, clear-cutting a forest, etc.).

Stable state/equilibrium: The condition to which a system (e.g., ecosystem) ultimately returns after disturbance.

Climax community: biological community which, through the process of ecological succession, had reached a steady state. (This equilibrium was thought to occur because the climax community is composed of species best adapted to average conditions in that area, or that can outcompete others that are well adapted.)

So, in post-fire (or other disturbance) chaparral or coastal sage scrub, there is an ecological succession that leads ultimately to the climax community. Members of the early successional stages are the fire followers we discussed in class and on our field trip. So, post-fire forays offer a narrow window of time in which to see some relatively rare and unique species whose destiny, in any particular area, is to be replaced by climax species…until the next disturbance anyways!

Allelopathy: The inhibition of one species of plant by chemicals produced by another species of plant.

An important biotic factor in chaparral communities is competition among plants. Plants all compete for the very limited water that is available during Mediterranean summers. One strategy for competing with neighboring plants is the production of allelopathic chemicals. These volatile or water-soluble chemicals are exuded by the chaparral shrubs and carried by the heat of the day or by water to the soil. The **allelopathic** agents may also leach out of the leaves or leaf litter to accumulate in the soil beneath. These compounds effectively stunt the growth of plants and reduce or eliminate seed germination. Allelopathy is a plant defensive mechanism. It ensures the limited moisture and nutrients available in the soil are only capable of being used by the plant producing the allelopathic chemicals.

A distinct pattern in some chaparral communities is spacing between some plants. Recall the photos from lecture of *Salvia leucophylla* (purple sage) and *S. apiana* (white sage). Chamise (*A. fasciculatum*) is another strongly allelopathic species. The "halos" around plants are often interpreted to result from allelopathy.

V. Coastal sage scrub

Coastal sage scrub: A plant community in Mediterranean climates in which the dominant plant species have the following general characteristics: short (≤ 3-6' tall), soft leaves (non sclerophyllous), shallow roots, summer deciduous leaves, aromatic (e.g., *Artemesia californica*, *Salvia* spp., *Mimulus aurantiacus* – bush monkey flower (we did not press this species in lab)), and occur on lowlands, typically near the coast – but interior sage scrub communities exist as well!

Coastal sage scrub communities are often referred to as "soft chaparral" because they have many similarities with chaparral: they exist near chaparral communities, have similar abiotic factors shaping them (drought, fire, dry & nutrient poor soils), often form ecotones with chaparral that can be quite broad, and share a number of plant species.

The term "soft chaparral" underscores an important structural difference between the two: whereas mature chaparral communities tend to be impenetrable thickets of woody braches, coastal sage scrub plants are "softer" to the touch, less densely populated, and leaves are thin (non-sclerophyllous). In some circles, chaparral communities were referred to as "hard" chaparral to distinguish them from "soft" chaparral – but this nomenclature is on the way out and is seldom used (but you will hear it!).

{VIDEO: sage scrub communities: http://www.youtube.com/watch?v=BuxticCTj7k}

Chaparral and coastal sage scrub communities are shaped by similar abiotic factors, especially drought and fire. Their adaptations to these factors, however, can be different and further distinguish the two communities. (Study the comparative table in these notes).

Drought: an extended period of water deficiency in a region. (Droughts are typically described as occurring over multi-year periods, but can occur on time scales of months or even weeks. Thus, it is reasonable to refer to dry & hot summers as drought-like or causing drought.)

Adaptation to drought: Recall that Mediterranean habitats are characterized by cool & wet winters and warm & dry summers – often this means summer drought conditions. Some sage scrub species are often **drought deciduous**, meaning that they lose some or all of their leaves in during drought conditions (summer). Most photosynthesis occurs in winter and spring when soil moisture is highest. These thin leaves are more vulnerable to herbivory than the sclerophylls of chaparral, and the conventional wisdom is that these plants produce essential oils in defense of herbivory.

Coastal sage scrub gets some relief from hot & dry summers due to cooler marine air temperatures and fog. The extent to which this is operative is variable among locations and across years, but it plays a part in the distribution of coastal sage scrub along the coast. It has been suggested that shallow roots assist with water absorption after fog/drizzle events.

Adaptation to fire: Unlike chaparral plants, which often recover from fire by sprouting from the roots (often from lignotubers / basal burls) or locally produced seeds (i.e., seeds produced by plants inside of a burn area), plants of the soft chaparral often rely upon seed delivered from outside of a burn area. Thus, these plants often have wind-mediated seed dispersal mechanisms. (Note: some species, such as the sages, produce seeds that germinate in response to fire, as with *Ceanothus megacarpus* in chaparral, and are not wind dispersed.) The shallow and low-biomass root systems of coastal sage scrub make them unlikely to re-sprout from the roots after fire.

After our field trip on chaparral and coastal sage scrub, you should be able to compare and contrast the important similarities and differences between chaparral ("hard chaparral") and coastal sage scrub ("soft chaparral"). The comparative table contained in these notes is something you might see on exams!

Coastal sage scrub conservation. most coastal sage scrub has been lost to development in southern California, primarily because flat land near the coast is highly desirable for human developments.

VI. Plant presses and herbarium specimens – see syllabus