## BIO 117 Plant Life History Strategies

### Tilman- Allocate Model

1. Plants have only a certain amount of photosynthate (sugar from carbon fixed by Photosynthesis).
2. Plants can allocate this differentially into leaf, root, stem, or reproduction.
3. Given this, they must allocate that to different parts of plant structure in a way that maximizes fitness through time.

According to Tillman's model how does this change with tissue loss? With nutrient supply (i.e. a proxy for productive capacity)

### Givnish- Stems Trade-offs

We can see that at some point, either hot or cold, limited nutrient supply, limited water, CO2 or some other factor will mean productive capacity is too low to build any plant materials and plants will thus be "infinitely short".

However, why can't plants be infinitely tall?

### General Strategies

We must also consider disturbance in the context of selective pressures on organismal life history traits. Those life history traits can be summed up in terms of four fundamental questions each organism and species must face. These are choices of:

1. How soon to reproduce? (Maturity)
2. How often to reproduce in its lifetime? (Parity)
3. How many offspring should be produced each reproductive cycle? (Fecundity)
4. When should an organism die? (Senescence vs. programmed termination)

### Maturity

How quickly after life begins should organisms begin to reproduce?
In making this choice, organisms must balance the **benefits** of an early reproductive effort (genes into the gene pool) with the **costs** that it entails (increased mortality and thus reduced likelihood of subsequent reproductive opportunities).

Thus, if there is a low probability of surviving to the next reproductive opportunity, it is best to breed early.

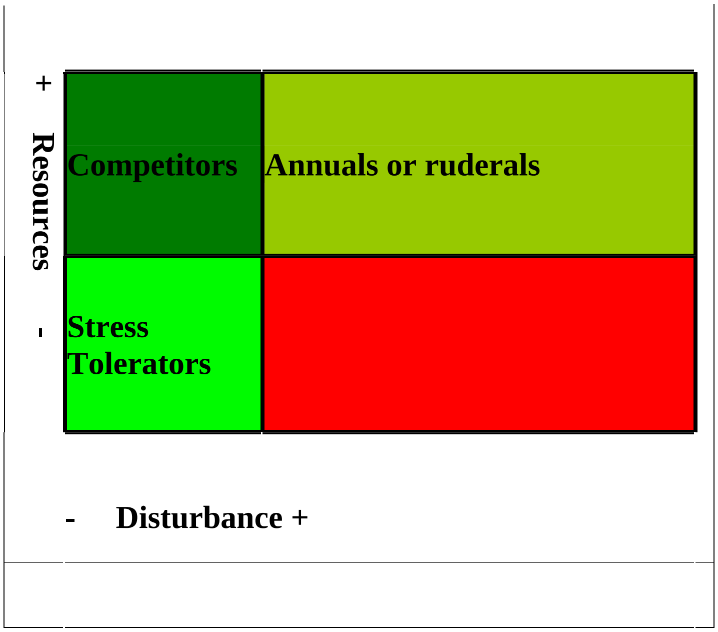
If survival is high, it may be best to wait.

### Annual vs. Biennial and Perennial plants

In general, there is a trade-off between adult survivorship and reproduction. In animals, reproducing early may stress the adults such that they have reduced survivorship. In plants, the same may also be true. Certainly every alloquat of photosynthate not used to make more leaves will reduce competitive ability for the next growth cycle. Therefore- If adult survivorship is good- and seedling establishment conditions poor then one should be a **perennial** and commit a fraction of photosynthate to reproduction every year. If adult survivorship is poor but seedling establishment conditions are good, then the optimal strategy is to be **annual**. Biennials are perennials that live two years, flowering and fruiting in the second year.

P.J. Grime splits this out as competitors, ruderals (annuals), and stress tolerators. (2X2 diagram; axes resource availability and disturbance; why one square missing plants?) Note that Grime originally presented this as a triangle. However, it is not necessary to invoke disturbance to get this pattern, as there are more general trade-offs between adult survivorship and juvenile mortality as discussed above. In addition, a more general rubric allows us to better understand many patterns in the landscape generated by disturbance

**Table 1- Grime's Life Histories**



| | Disturbance - | Disturbance + |
|---|---|---|
| Resources + | **Competitors** | **Annuals or ruderals** |
| Resources - | **Stress Tolerators** | 🟥 |

Please note the similarities of Grime's scheme to Tilman's diagram for allocation patterns in his ALLOCATE model. Though they have disagreed vehemently in the ecological literature, they are not so far apart in what factors shape life history strategies in plant communities. This is especially true when Grime's ideas are seen in the perspective of a 2x2 diagram rather than a triangle. Draw a 2x2 diagram of Tilman's allocation patterns for stem, leaves, and roots across nutrient and disturbance (loss) gradients.

## Parity

Some species that live for several to many years but reproduce only once -- in a single massive effort. This type of strategy is **semelparity** in contrast to **iteroparity** where individuals engage in multiple reproductive bouts. Examples include bamboo, and agave (century plants), and most generally- all annual plants. What advantages could semelparity offer?

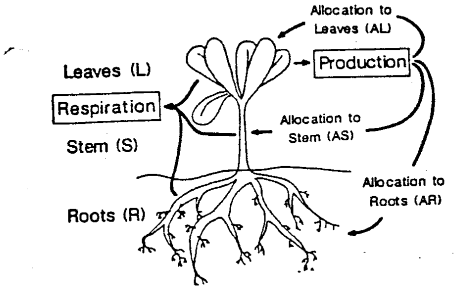
## Fecundity: The Numbers Game

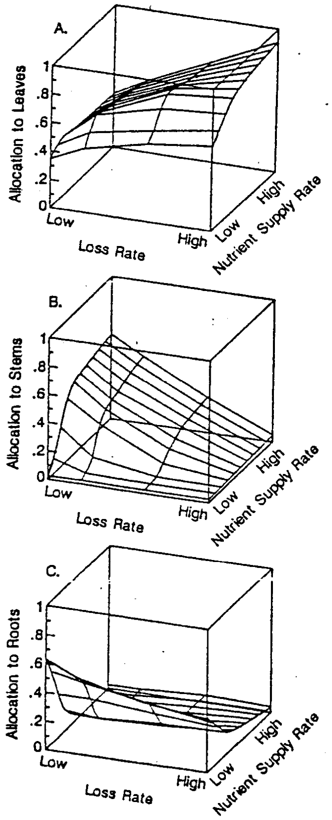
What is the optimum strategy for organisms that will live to reproduce more than once? They should not over-emphasize fecundity that jeopardizes future reproductive opportunity: because ultimately fitness is judged OVER THE ENTIRE LIFESPAN!

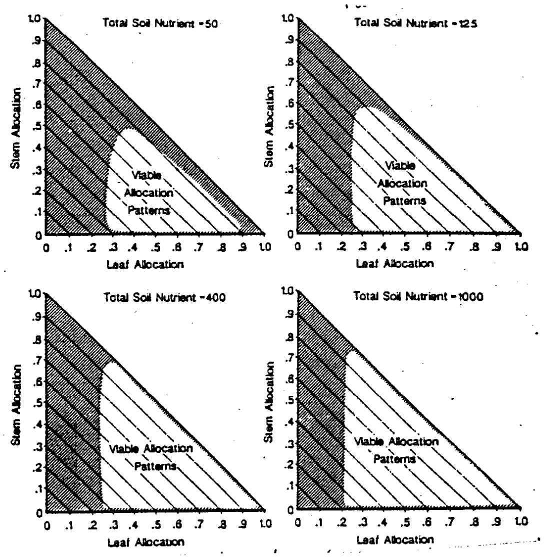
In organisms, generally- bigger size means more energy available to make little babies. If an individual has **indeterminate** growth (continues to grow throughout their life rather than reaching a fixed adult size), the initial emphasis should be on growth to permit much greater subsequent reproductive efforts, and a delay in **maturity**. However, in waiting too long, the creature may risk death before passing on any genes. Thus, in some organisms there is a bet hedging done by switching sex with age or size (sequential hermaphrodites)!

**Think of how four fundamental life history questions and Grimes' Life History Strategies help interpretation of the disturbance-induced patterns discussed in your text.**

Fire History
Wind
Tectonic Activity
Flooding
Forest Stress Syndrome
Animals and Humans







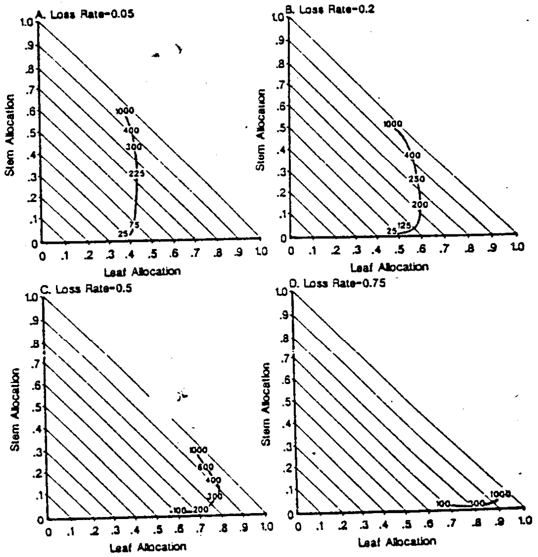


FIGURE 4.8. Competitively superior morphologies for plants that are identical in every way except their allocation patterns. Note that different allocation patterns are favored at different loss rates. Higher loss rates favor plants that have higher leaf allocation, but lower root or stem allocation, because higher loss rates cause increased availability of soil resources and light at the soil surface.

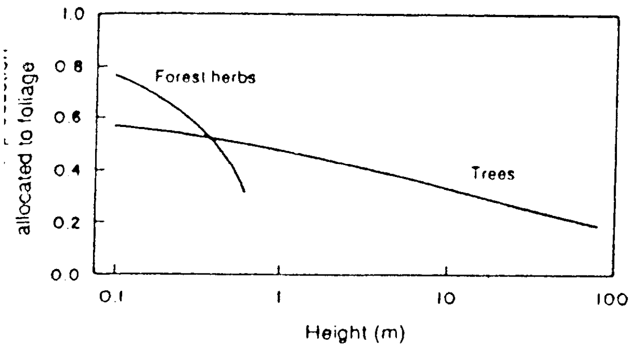


**Fig. 4.** Proportion of annual biomass production allocated to foliage as a function of plant height. The curve for trees is based on allometric regressions given by Whittaker and Woodwell (1968), root production estimated as 20% of stem production, and a 71% allocation to leaves in the leaf-twig fraction of *Liriodendron* (Whittaker *et al.* 1963). The curve for forest herbs is based on data of Givnish (1982), but excludes root production.

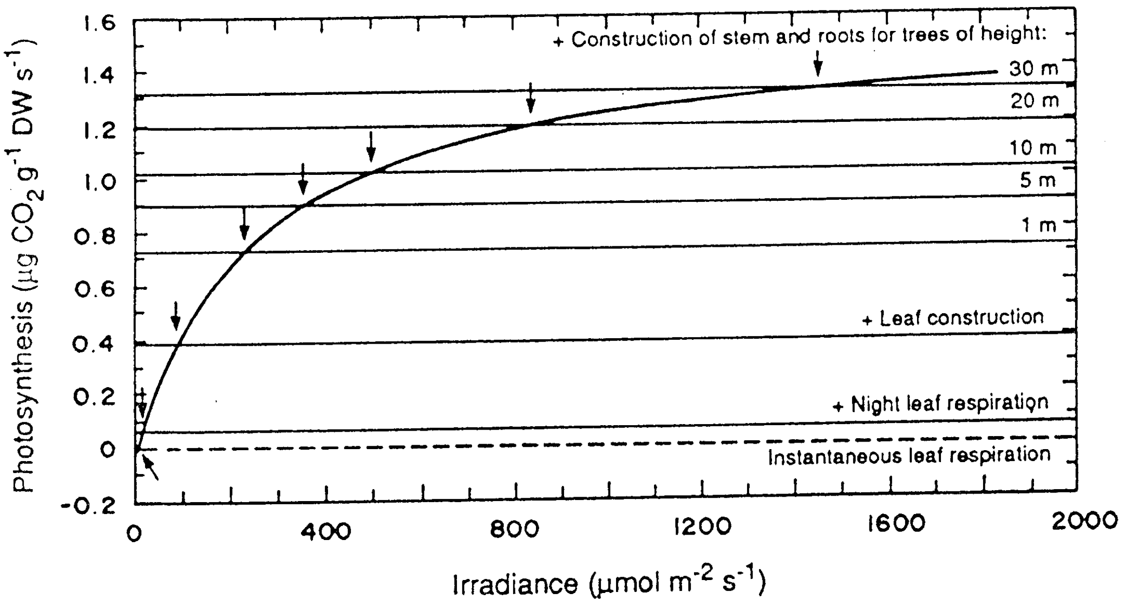


**Fig. 3.** Effective leaf compensation point in *Liriodendron tulipifera* as a function of the inclusion of various respiratory costs. The curve is the instantaneous rate of net leaf photosynthesis, plotted as a function of irradiance; the dashed line is the instantaneous rate of leaf respiration; the arrow at their intersection marks the traditional compensation point. The solid lines represent the cumulative respiration rates associated with night leaf respiration, leaf construction, and construction of support and root tissue (see text); the corresponding arrows mark the effective compensation points associated with including each additional source of respiration.

**Table I** Summary of the Five Principal Trade-Offs Involving Stem Traits Discussed in Text

| Trade-off | Basis | Prediction(s) |
|---|---|---|
| **Mechanical safety vs growth and competitive ability** | Stems with a higher margin of biomechanical safety have higher rates of survival or withstand greater stresses, at the cost of lesser stature or greater allocation to stem tissue at a given height | 1. Species adapted to a high degree of mechanical stress should be competitively excluded from less stressful environments; species adapted to the latter should be unable to survive in mechanically stressful sites, even in the absence of competition<br>2. Shade-intolerant, short-lived pioneers should have lower mechanical safety margins than shade-tolerant, long-lived species of similar stature |
| **Growth vs photosynthetic requirements** | Taller plants have an advantage in competing for light, but must allocate more to unproductive support tissue. The competitive advantage of greater stature is greatest where coverage is dense | 3. Productive, infrequently disturbed habitats favor heavy allocation to stem tissue and high stature, at least among late-successional dominants. Tall plants may be unable to survive in unproductive habitats<br>a. In herbs, leaf height should increase with the density of competing foliage<br>b. In woody plants, maximum height should be strongly influenced by the height-dependent pattern of allocation to support tissue<br>c. Treelines should occur where low levels of light, soil moisture, or temperature strongly limit photosynthesis and cause woody plants to reach their energetic break-even point close to the ground. Woody plants should generally also be unable to invade sodden soils, given the constraints on aerenchyma function imposed by secondary thickening<br>d. Emergent, floating, and submersed herbs should dominate progressively deeper bands of water, reflecting the relationship between stature and support costs at a given depth seen across growth forms |
| **Initial vs continuing costs** | Woody tissue has a higher initial cost of construction than mechanically equivalent herbaceous tissue, but lower continuing costs because only a fraction must be replaced each year | 4. Tall, woody plants should be less shade tolerant than shorter or more herbaceous species<br>5. Dominance in temperate forest understories should shift from shrubs to herbs in moving toward moister, more fertile, shadier sites<br>6. Compound leaves should be favored in gap-phase succession or in seasonally arid environments that favor deciduous foliage, where there is an advantage in bearing short-lived twigs/rachises |
| **Photosynthetic vs mechanical efficiency** | Branching patterns and leaf arrangements that reduce leaf overlap and competition for light often require more investment in stem tissue, or involve exposure to greater irradiance and transpiration | 7. Shade-adapted plants should be plagiotropic and show distichous phyllotaxis, and sun-adapted plants should be orthotropic and show spiral phyllotaxis<br>8. Branching angles should minimize both leaf overlap and structural costs, if possible<br>9. Efficient leaf packing in shade-adapted, distichous species favors alternate leaves (or anisophylly in lineages with opposite leaves), as well as asymmetric leaf bases |
| **Self-support vs structural parasitism** | Structural parasites allocate far less to stems to achieve a given height than do self-supporting plants, resulting in greater rates of vertical and horizontal growth. However, vines require self-supporting hosts on which they climb, their slender stems make them vulnerable to certain environmental stresses, and their climbing mechanism enables them to climb only certain kinds of hosts | 10. Vines should be most common in frequently disturbed habitats with an intermediate amount of coverage by self-supporting plants; they should be rare in arid, nutrient-poor, and/or fire-swept environments<br>11. Tendril climbers should ascend hosts of the finest diameter; twiners, hosts of greater diameter; and adhesive-root climbers, hosts of the greatest diameter<br>12. In habitats where vines are abundant, hosts should evolve traits that deter climbing by vines, such as frequently shed compound leaves or shaggy, exfoliating bark |