Chapter 2: Systems

- Components (individual parts)
- State of a system (attributes)
- Links or couplings (allow flow of information)
  - Positive 
  - Negative 
- Feedback loops (round-trip couplings)
  - (Rule about overall effect)

Cheesey example: President and Rosalynn Carter

Positive and Negative Feedback

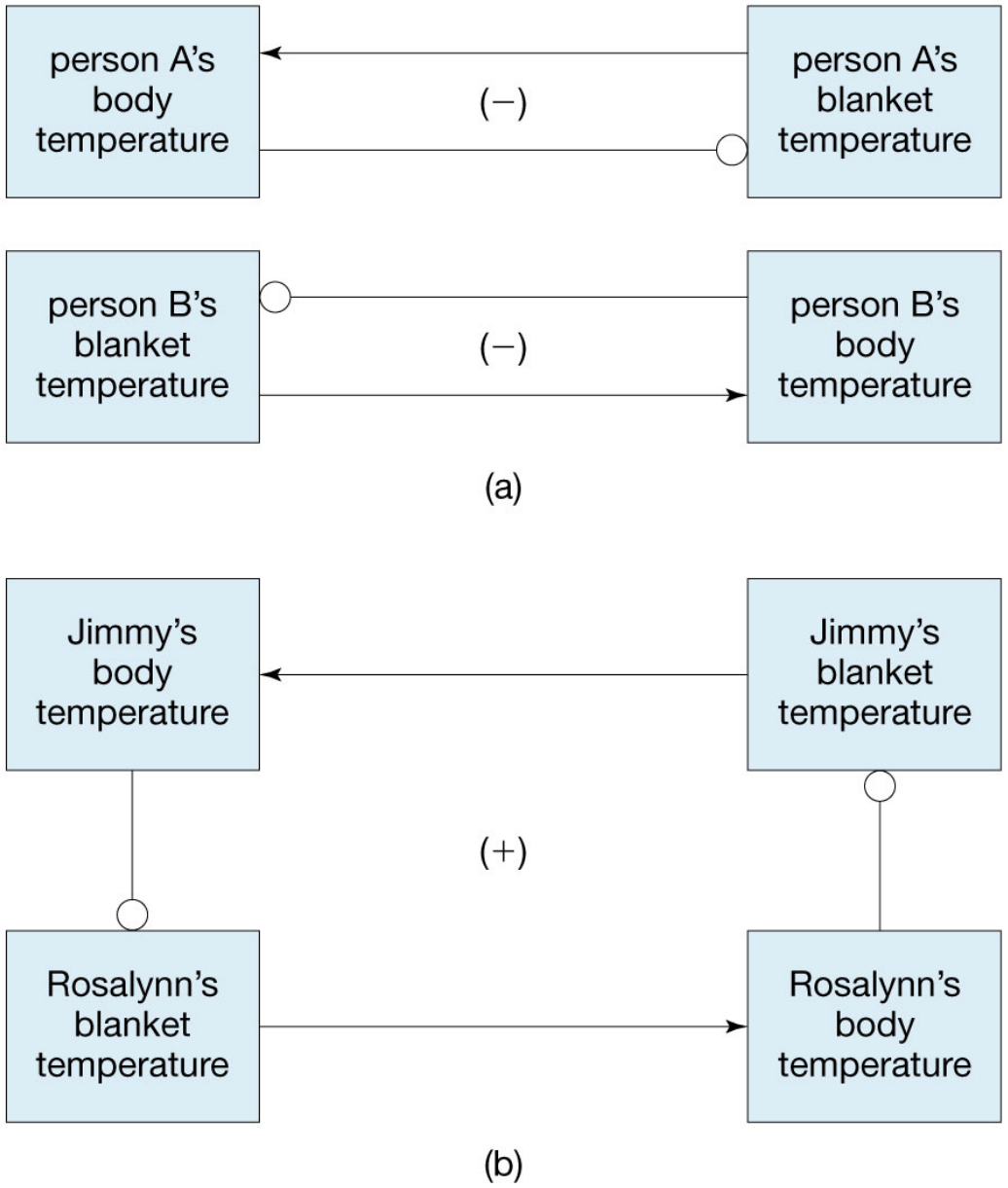
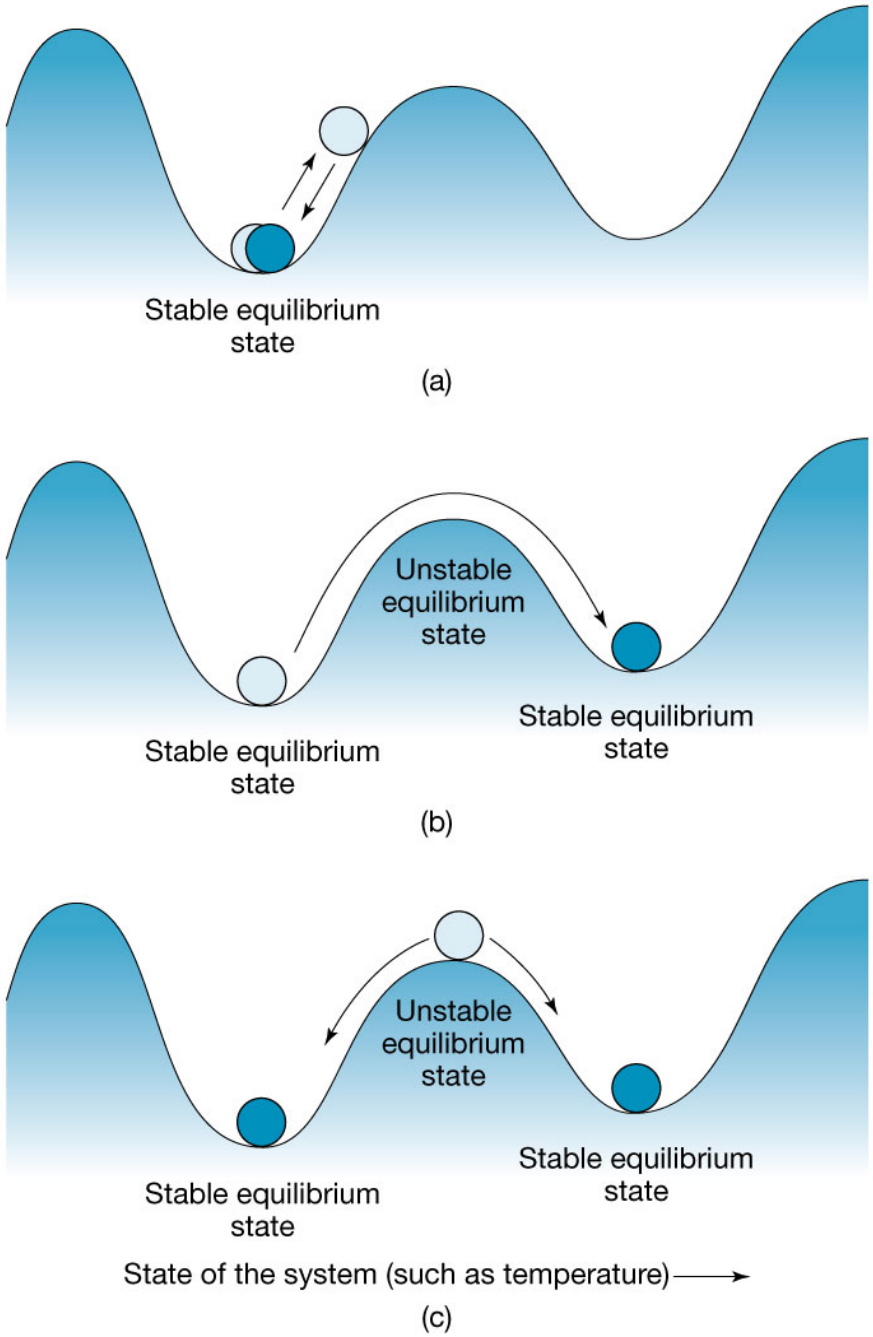


Fig. 2-2

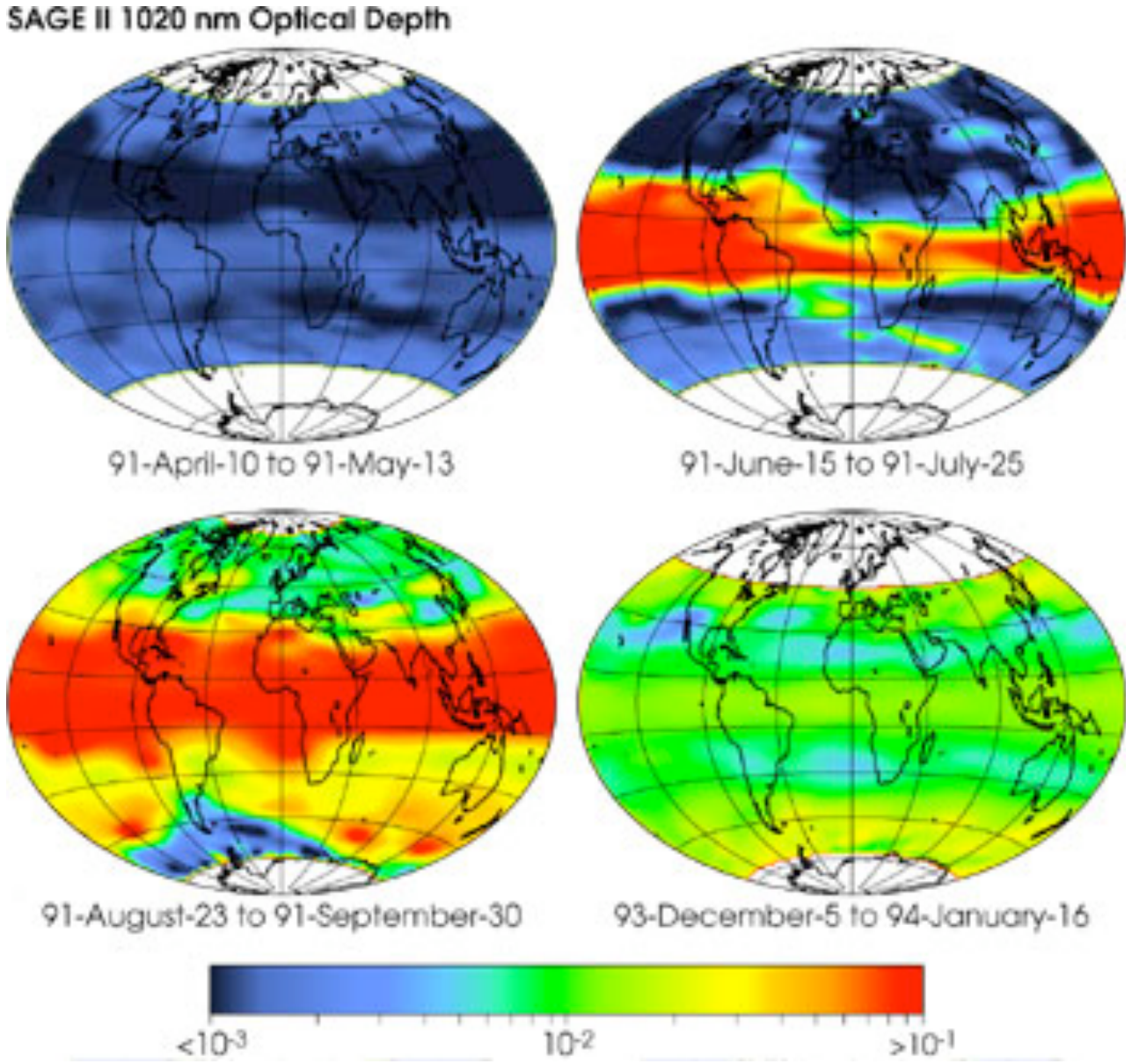
Equilibrium State:

- System shows no visible sign of change, and does not change if it is not disturbed
  - **Stable equilibrium state**: if system is disturbed it will return to its original equilibrium state
  - **Unstable equilibrium state**: if the system is disturbed, the system will be carried farther and farther from its equilibrium state

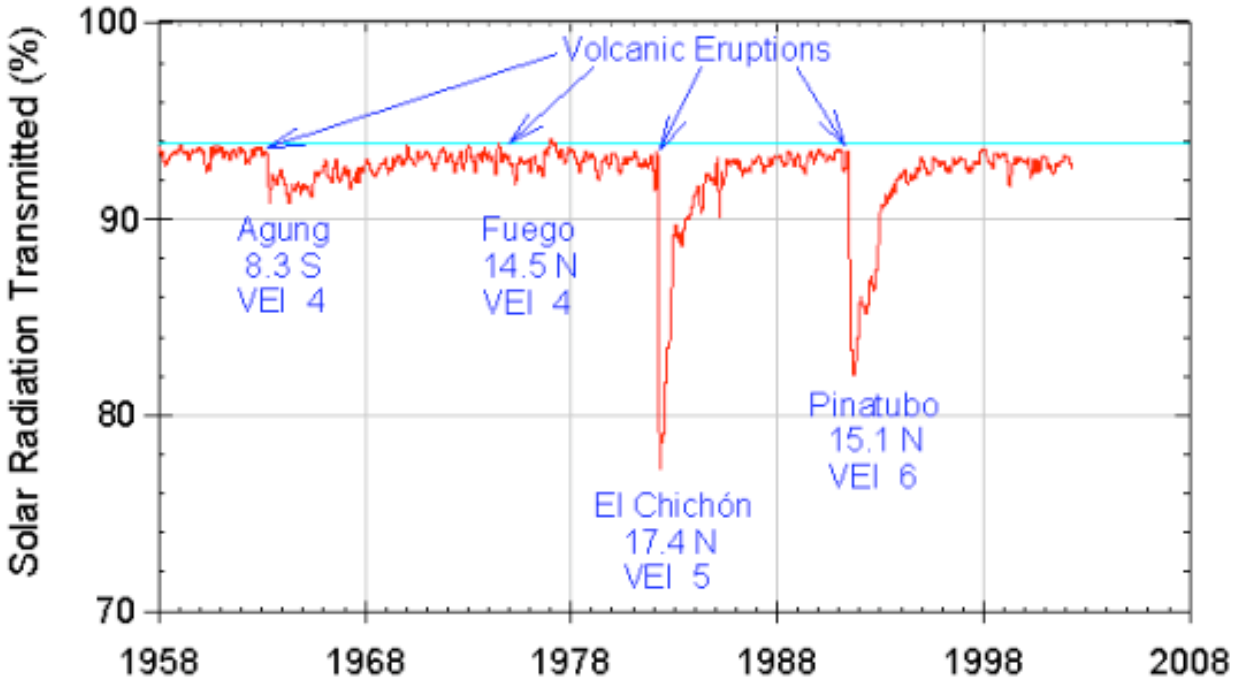
Fig. 2-3



Mt. Pinatubo, June 1991


SAGE II 1020 nm Optical Depth
91-April-10 to 91-May-13
91-June-15 to 91-July-25
91-August-23 to 91-September-30
93-December-5 to 94-January-16
<10-3
10-2
>10-1

Mauna Loa Observatory Atmospheric Transmission



Perturbations: temporary disturbance of the system

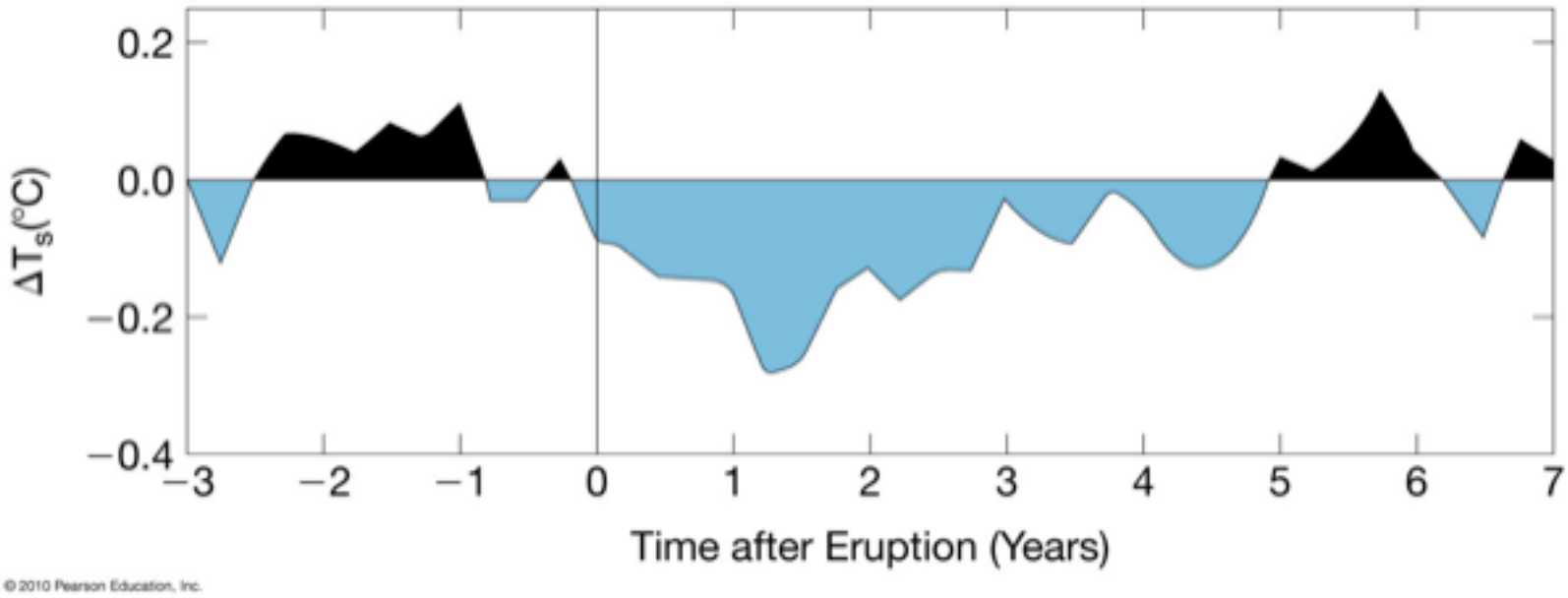


Fig. 2-4

Injection of SO_2 into atmosphere (by volcanoes or burning fossil fuels) forms sulfate particles that prevent sunlight from reaching Earth's surface.

Albedo = reflectivity of a surface:

TABLE 2-1 Albedos of Some Common Surfaces

Type of Surface	Albedo
Sand	0.20–0.30
Grass	0.20–0.25
Forest	0.05–0.10
Water (overhead Sun)	0.03–0.05
Water (Sun near horizon)	0.50–0.80
Fresh snow	0.80–0.85
Thick cloud	0.70–0.80

Low number = more solar energy is absorbed
High number = more solar energy is reflected

Forcings: persistent disturbance of the system

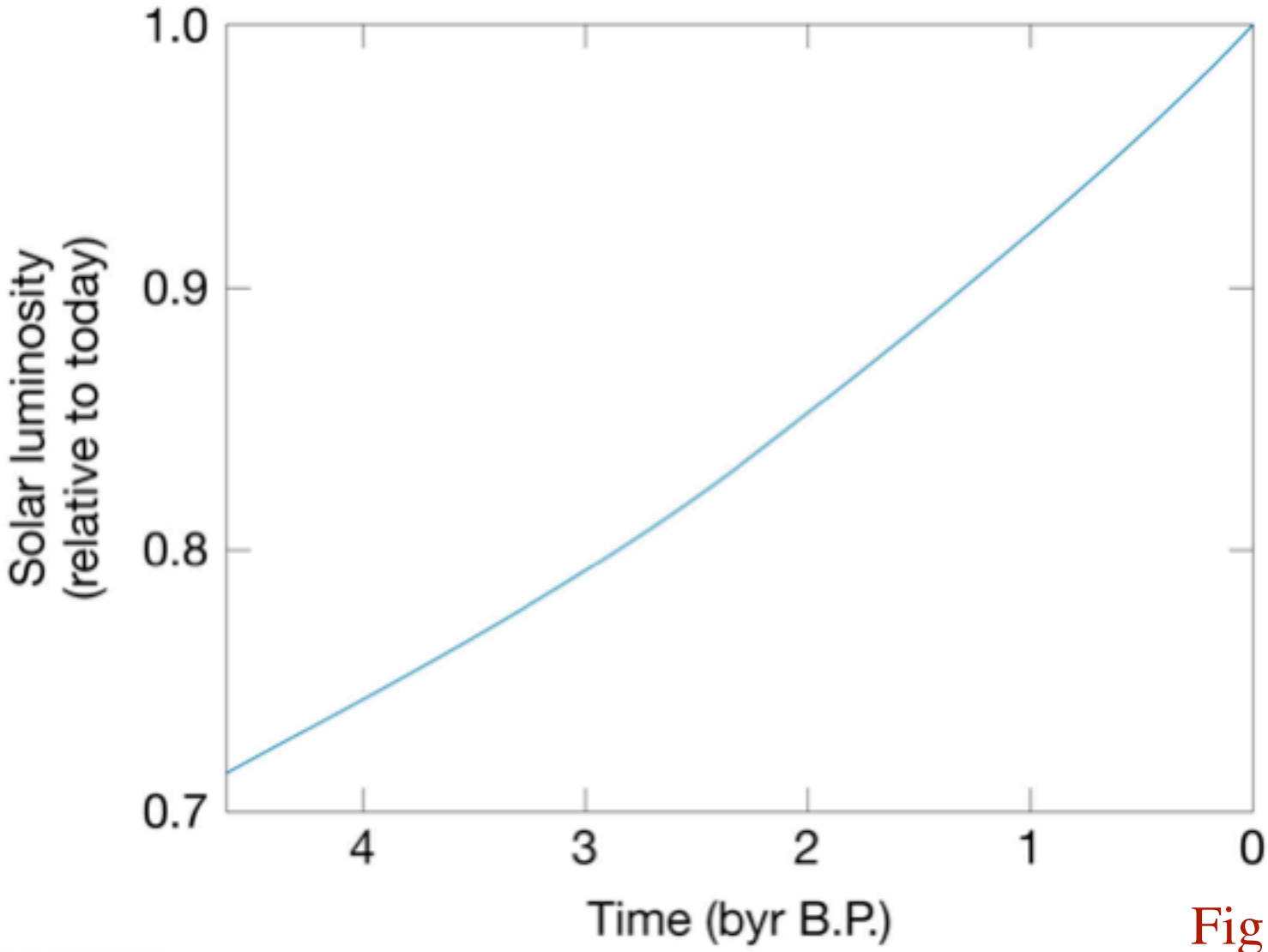


Fig. 1-13

“Daisyworld”

Daisy covered areas reflect more light away.

Temperature of planet depends on how much of its surface is covered by daisies.

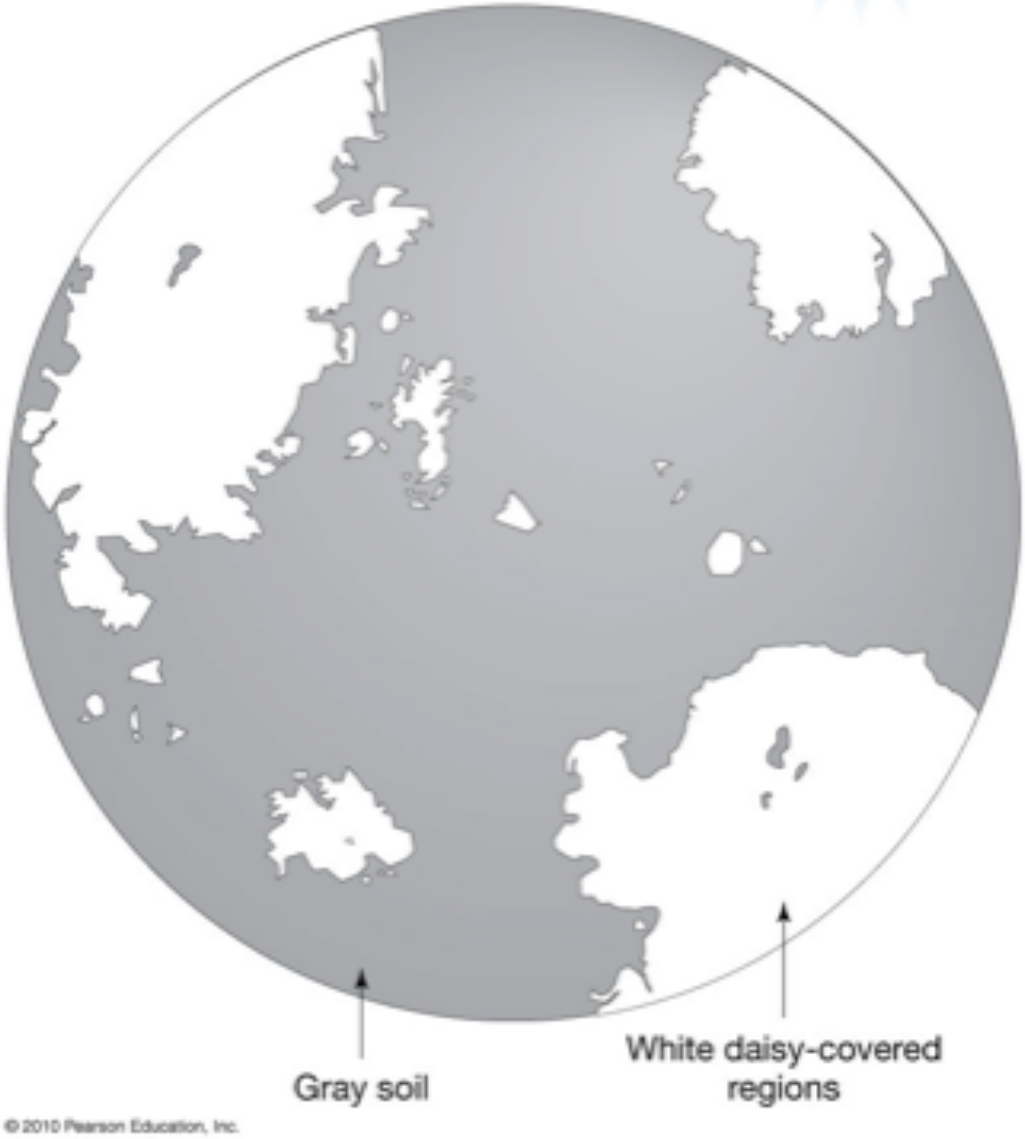


Fig. 2-5

Fig. 2-7

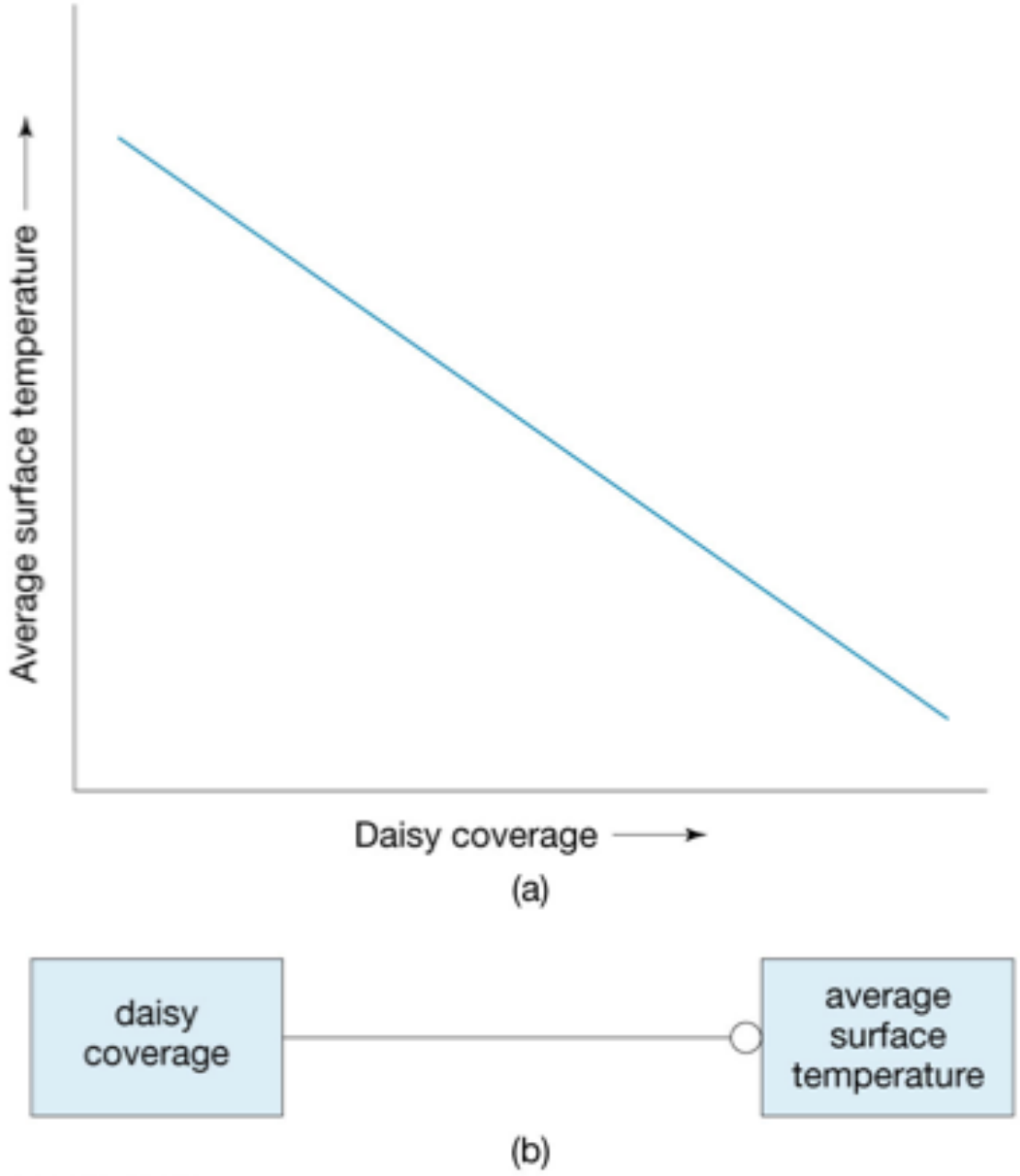


Fig. 2-8

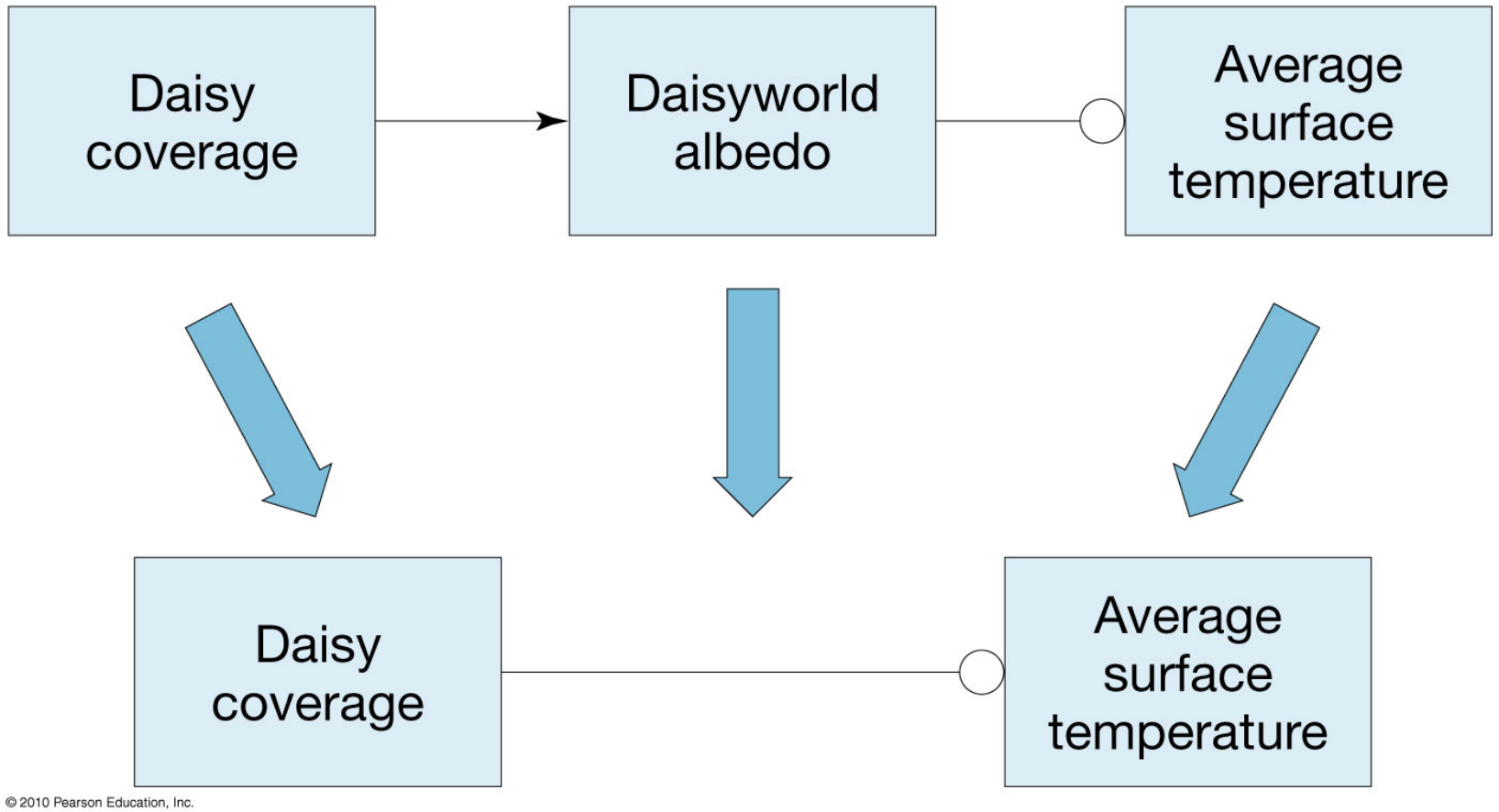


Fig. 2-9

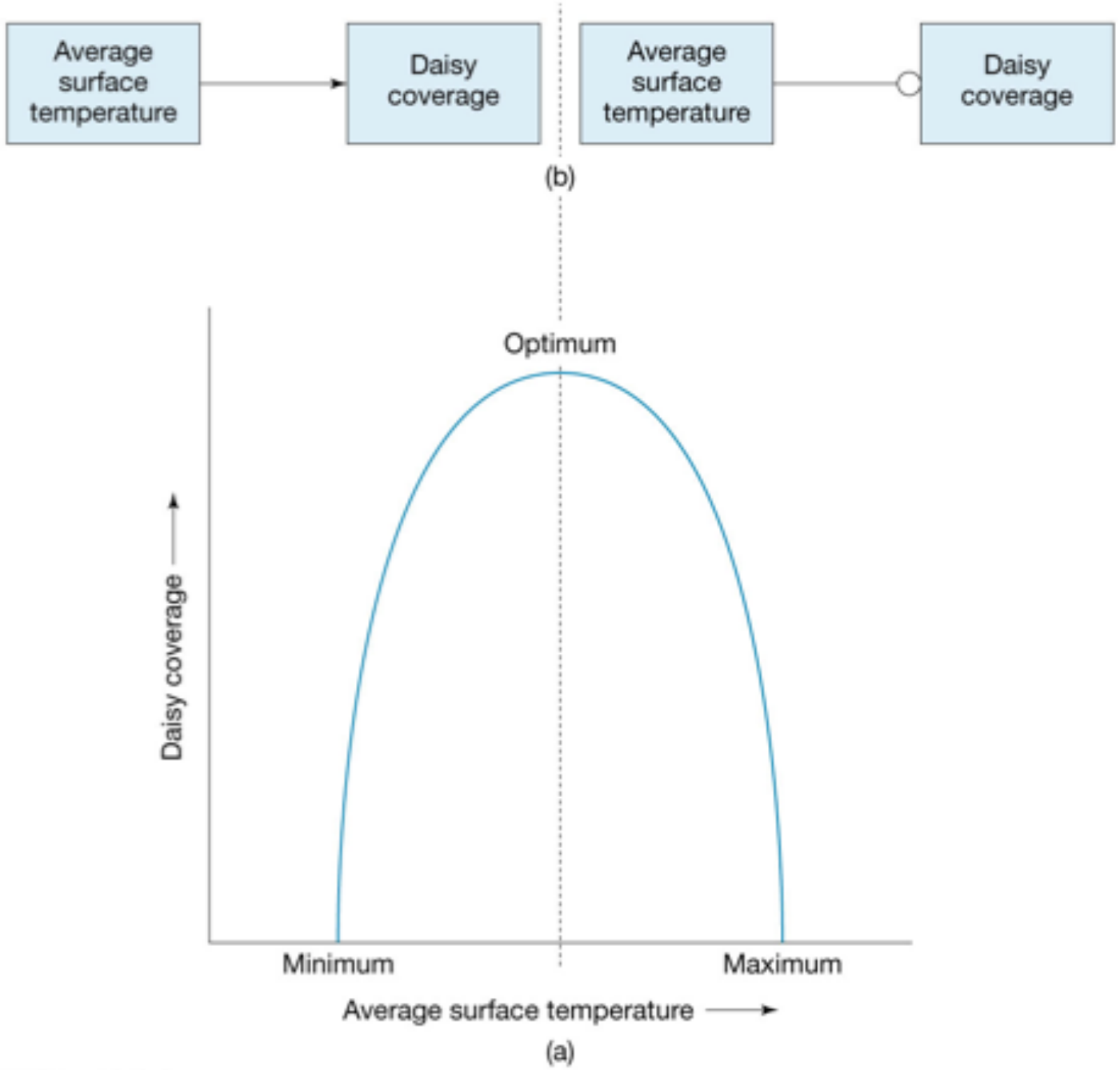


Fig. 2-10

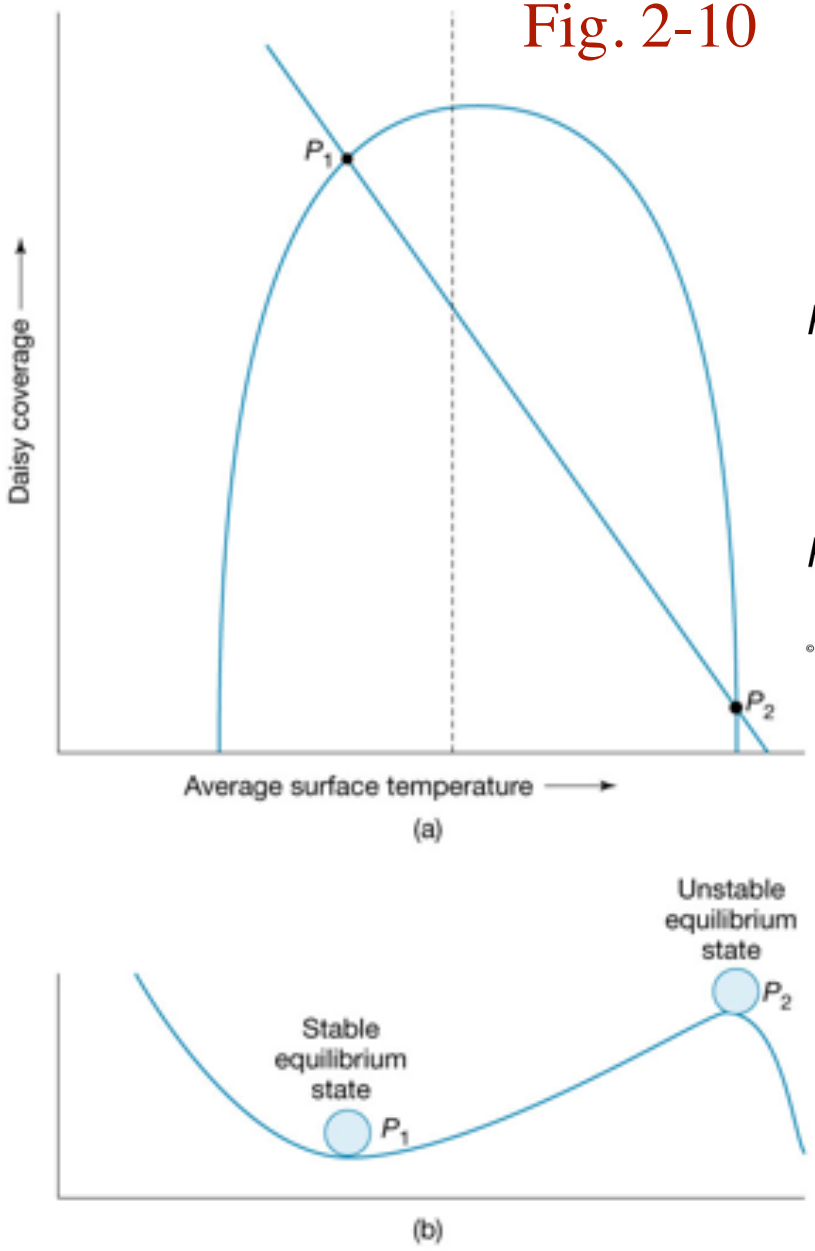


Fig. 2-11

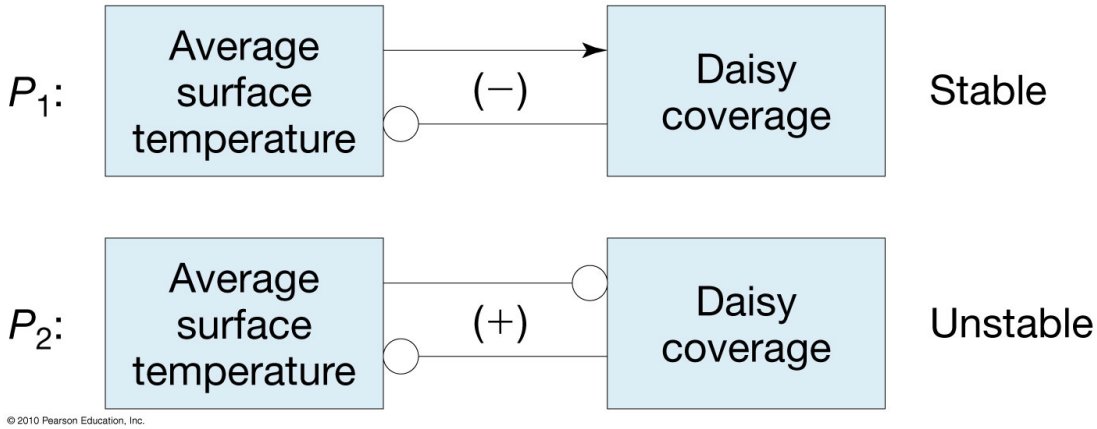


Fig. 2-12: Effect of forcing

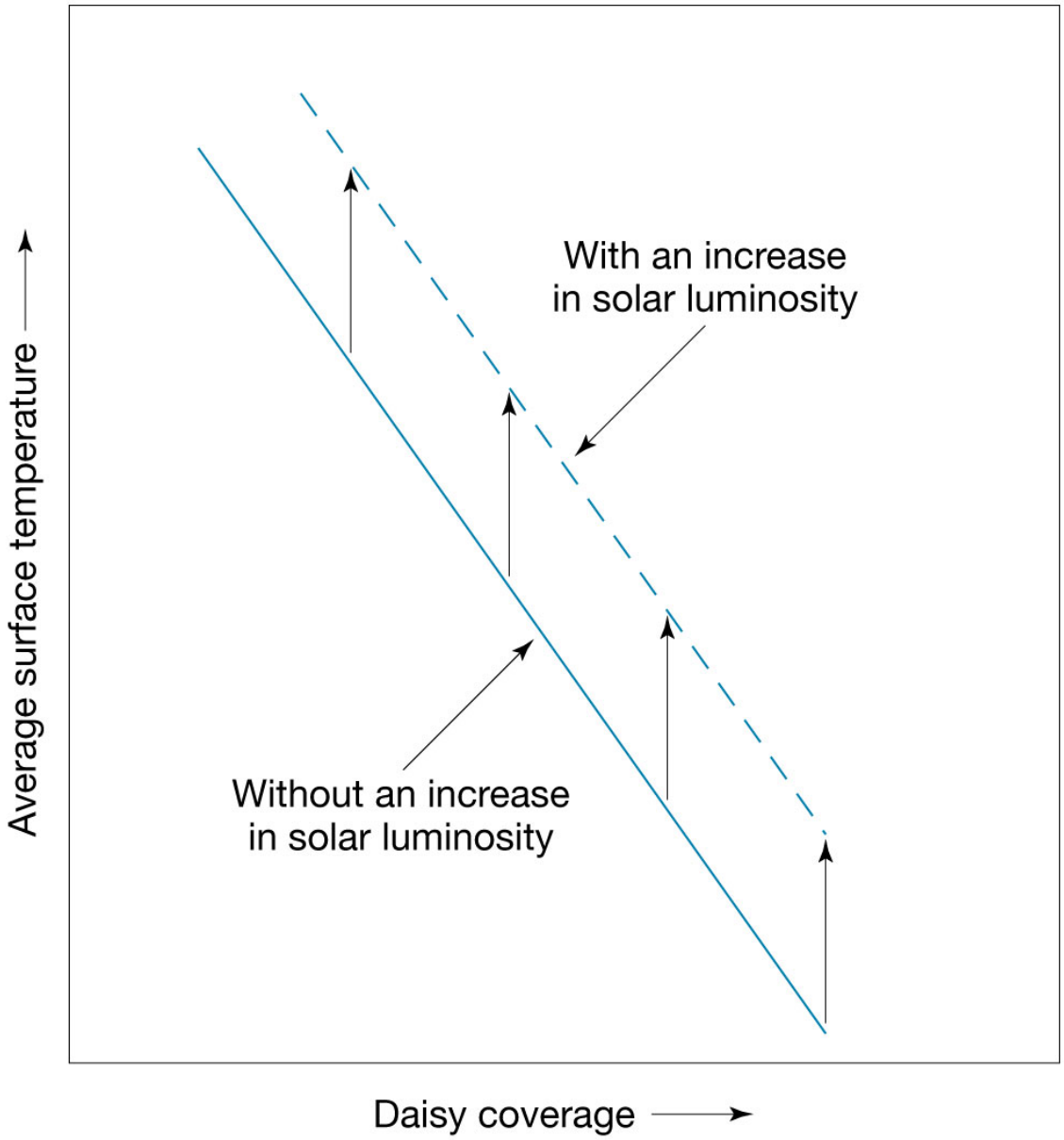


Fig. 2-13

Rising solar input moves the line depicting the dependence of temperature on daisy coverage upward, which has the effect of moving P_1 to P_1' (closer to the high point of the parabola) – which makes the P1 state less stable:

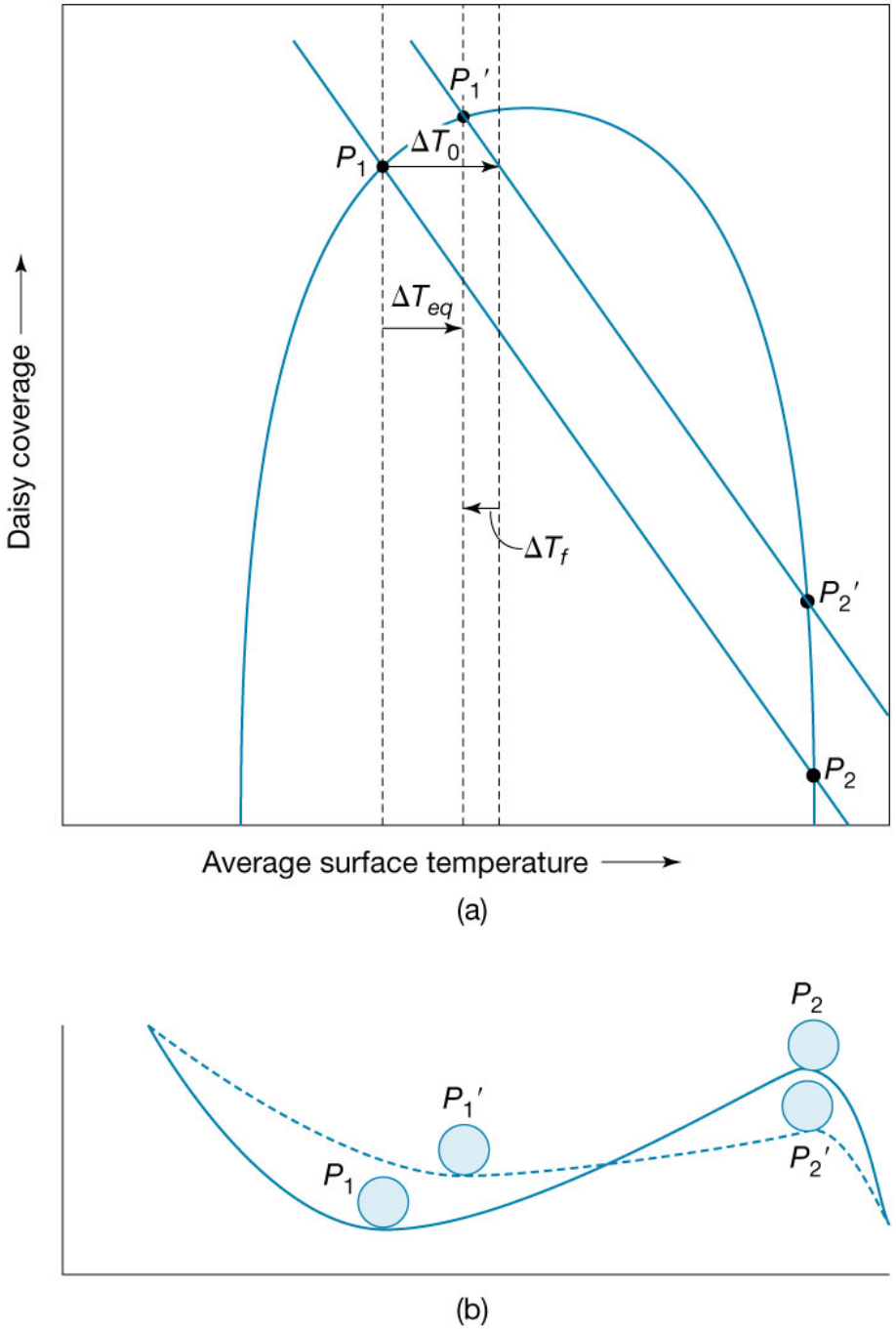
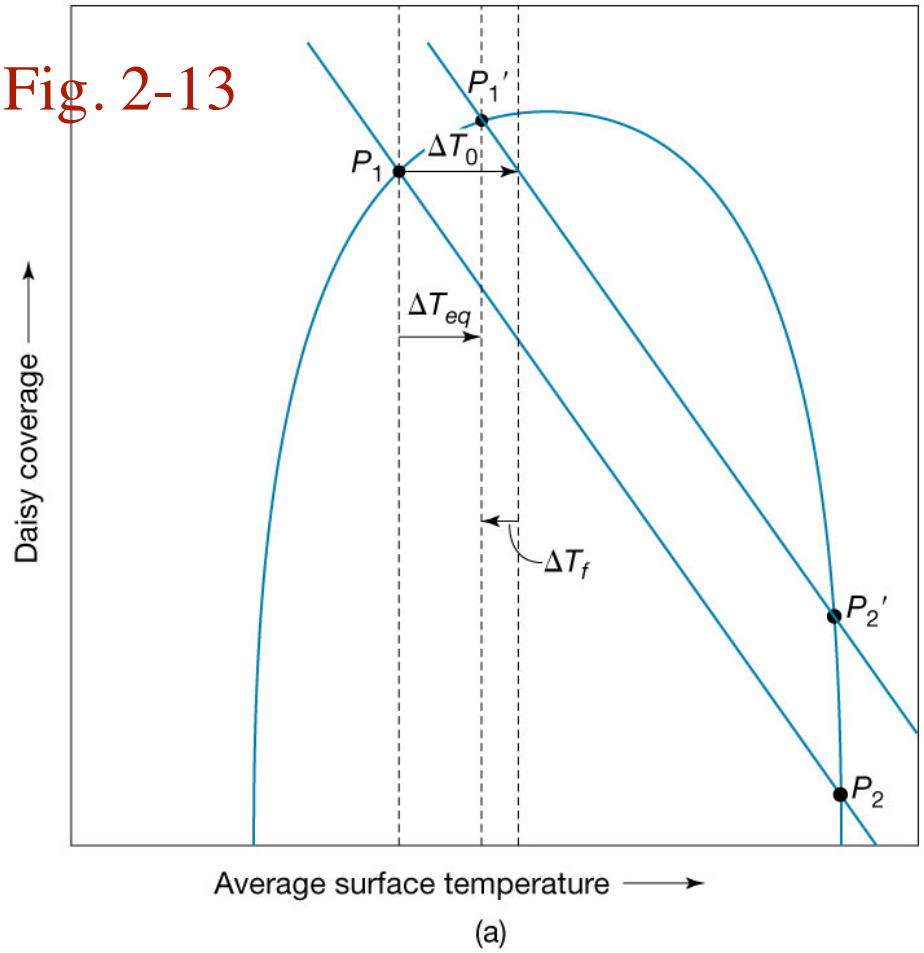
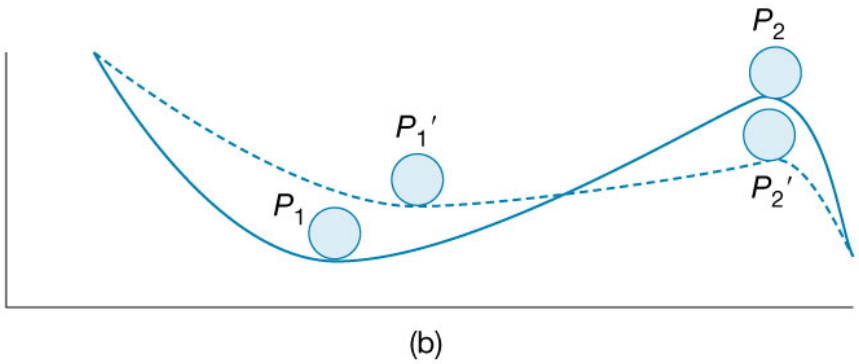


Fig. 2-13





ΔT_o = T change w/o feedback

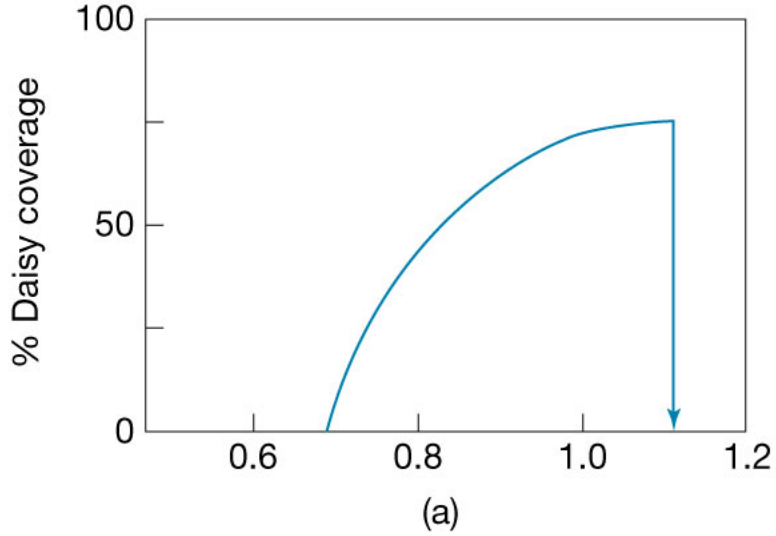
ΔT_{eq} = T change w/ feedback

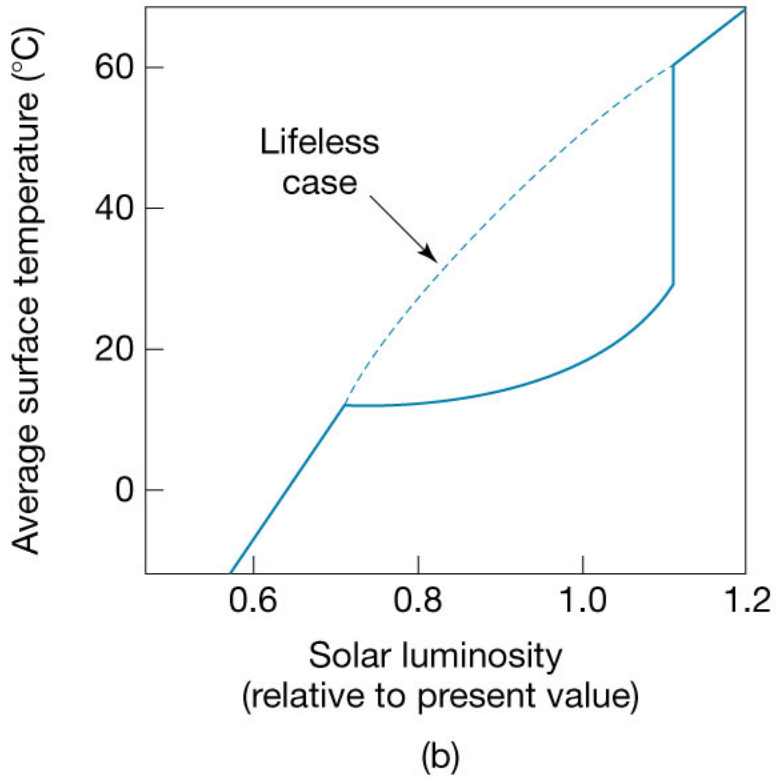
ΔT_f = T change of feedback effect

Feedback effect:
$f = \Delta T_{eq} / \Delta T_o$

f<1 is neg. feedback
f>1 is pos. feedback

Fig. 2-14: Quantifying Daisyworld





Daisyworld tells us

- Climate systems have feedback loops that respond to perturbations and forcings
- Response is not "intelligent", but the system can be self-regulating
- It isn't necessarily optimal or perfect
  - Daisyworld response to solar luminosity increase dampens the T increase but does not stop it
  - Daisies do not get to live at their optimum temperature!