The microprocessor problem

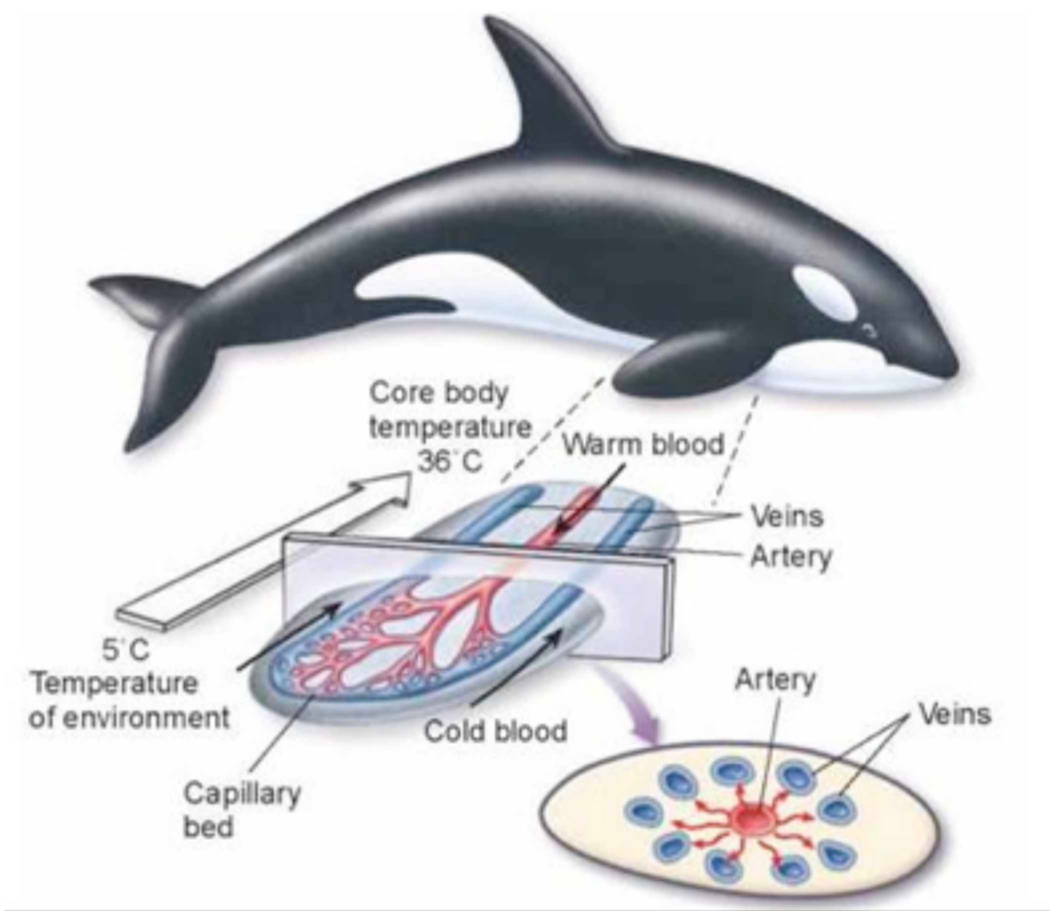
How do you design the radiator of a $10 cm^2$, 50 W microprocessor ?

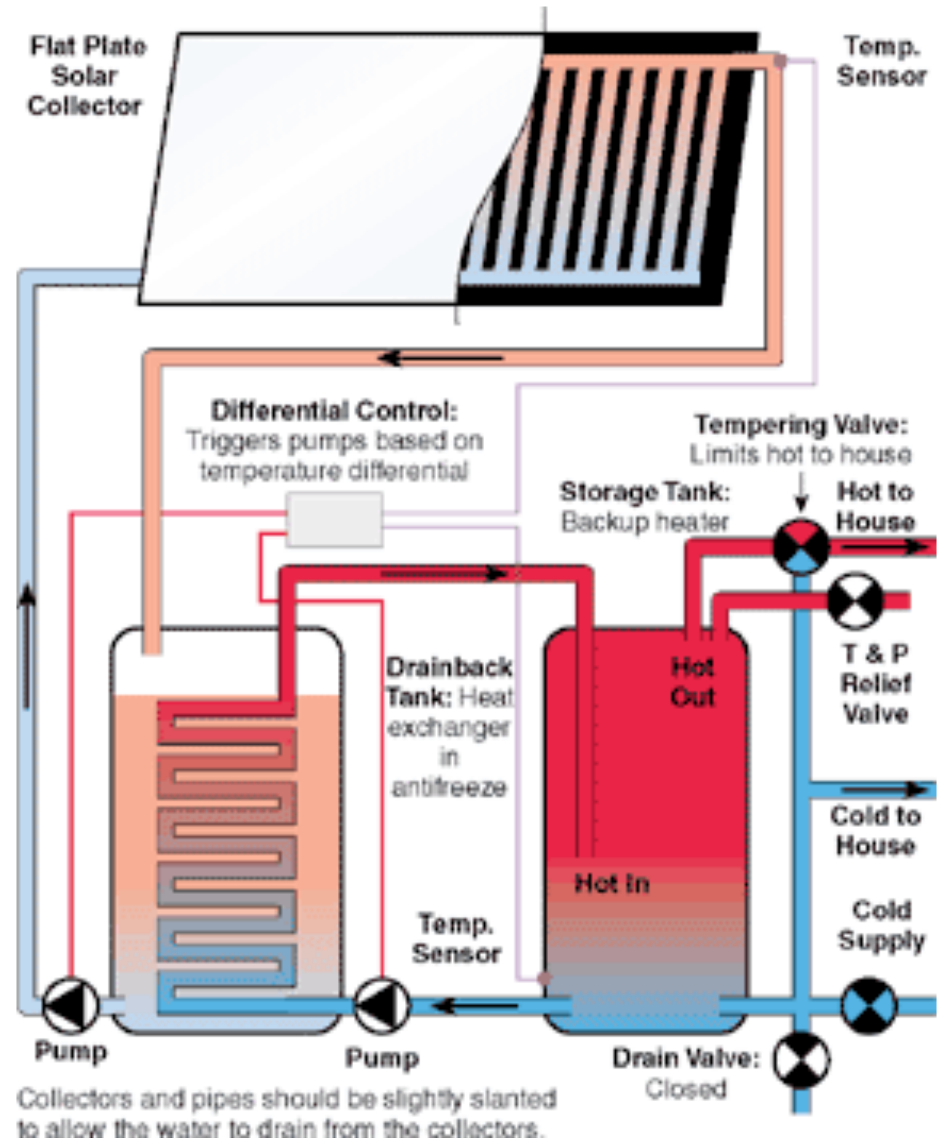
If we rely only on diffusion in air,we can dissipate 0,2 W

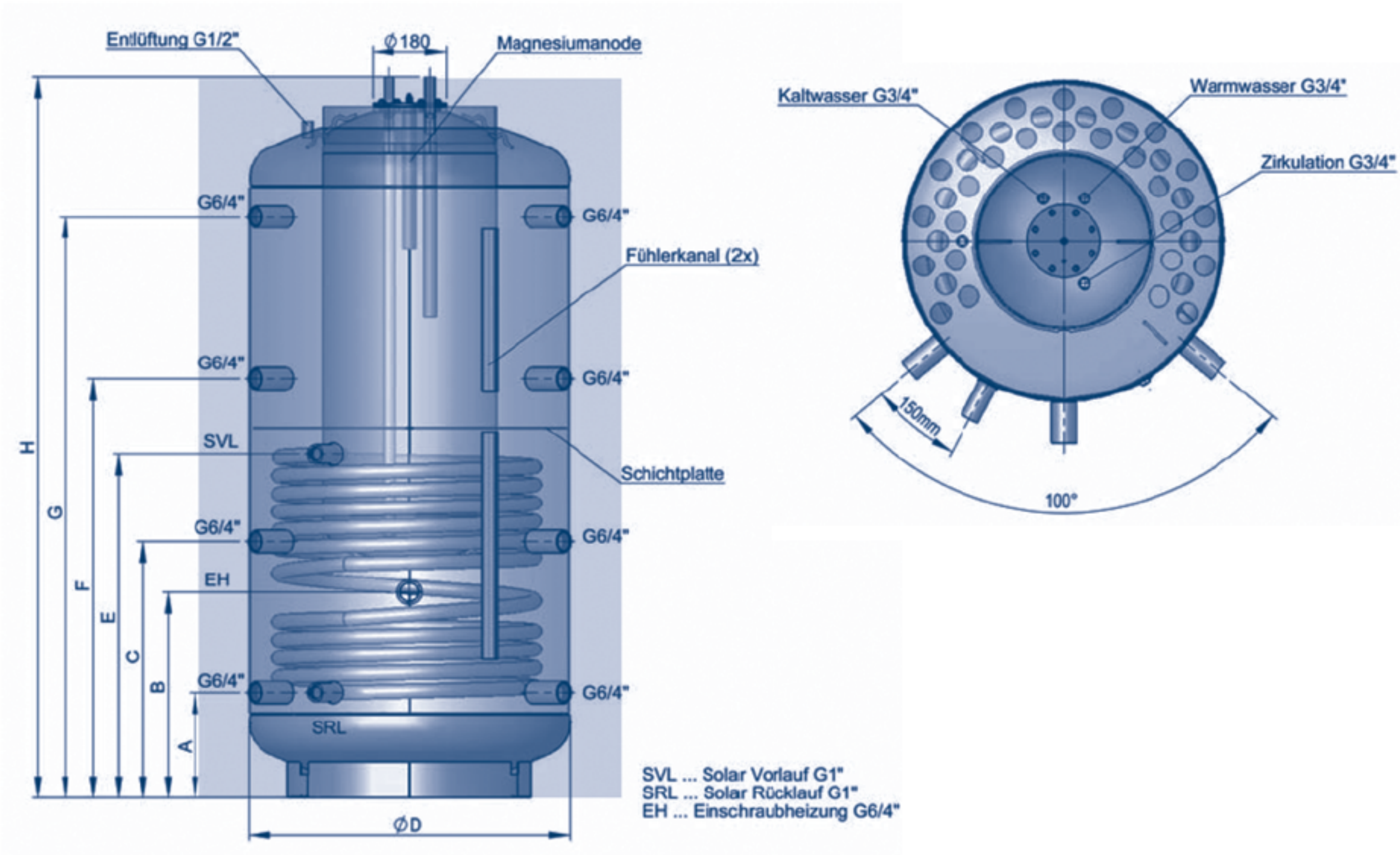
We can increase the flux by adding a series of fins, but there is an optimum length L_m for fins depending on their thickness e and the heat transfer coefficient h. $L_m \sim (e\, \lambda_{aluminum}/h)^{1/2}$

Remaining questions :
what is the value of the heat transfer coefficient between fins and air ?
Assuming Poiseuille flow of air between the fins and thermal boundary layer smaller than the spacing between fins, the heat flux is given by the same expression as in the microchip problem
what is the flow rate of air Q required ?
Write the macroscopic balance for heat exchange:
$Q\, C\, (T_{out} - T_{in})$ = dissipated power 50 W

heat exchangers







storage tank of a water solar heater with the heat exchanger
(from energiedirekt a german manufacturer of solar heaters)

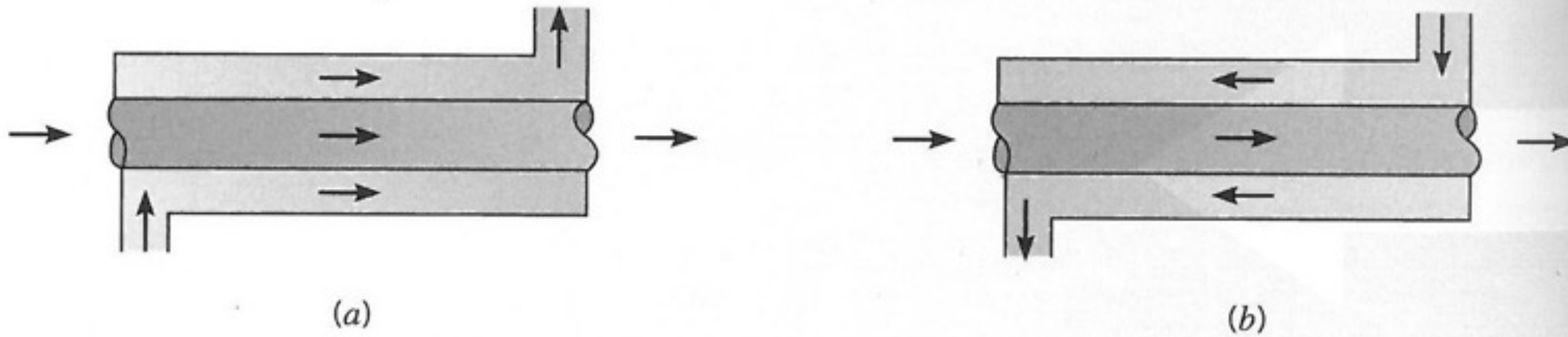
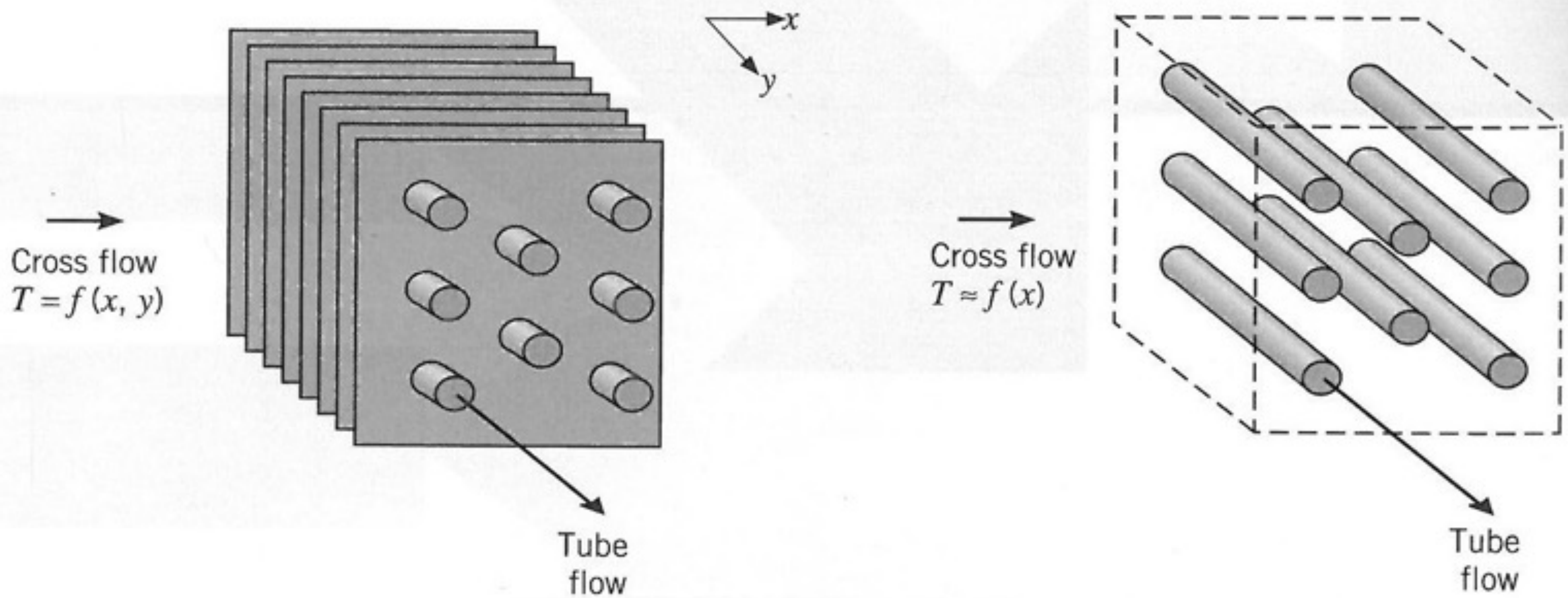
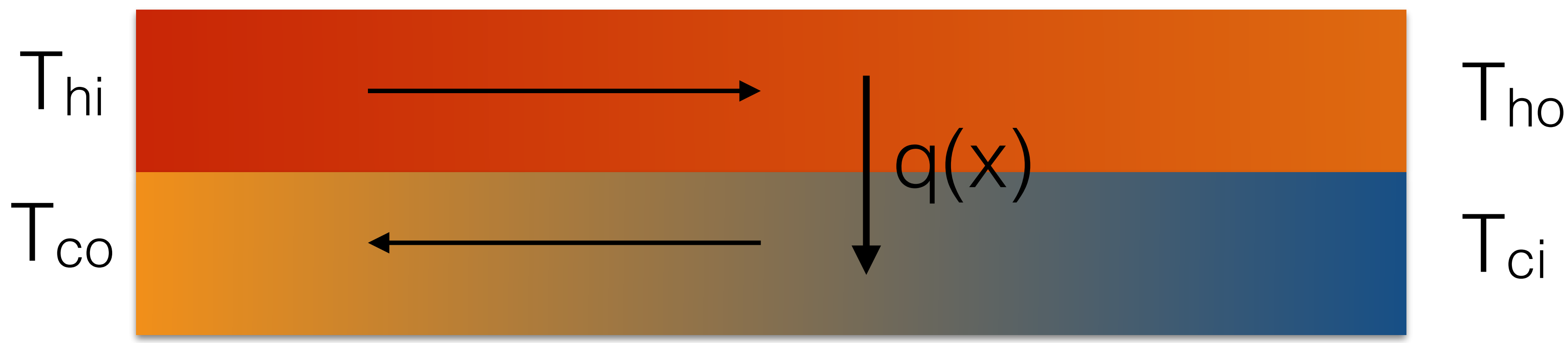


FIGURE 11.1 Concentric tube heat exchangers. (*a*) Parallel flow. (*b*) Counterflow.

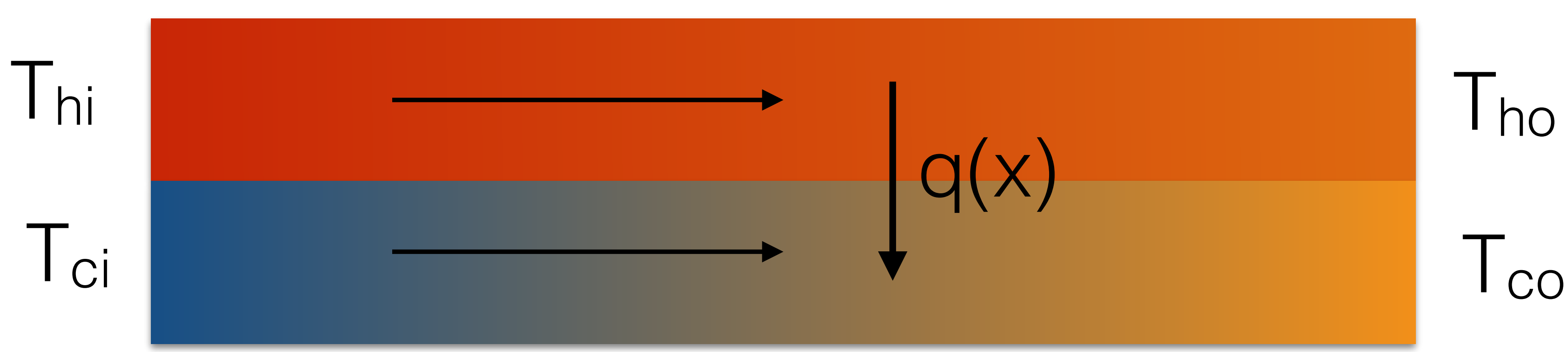


different types of heat exchanger

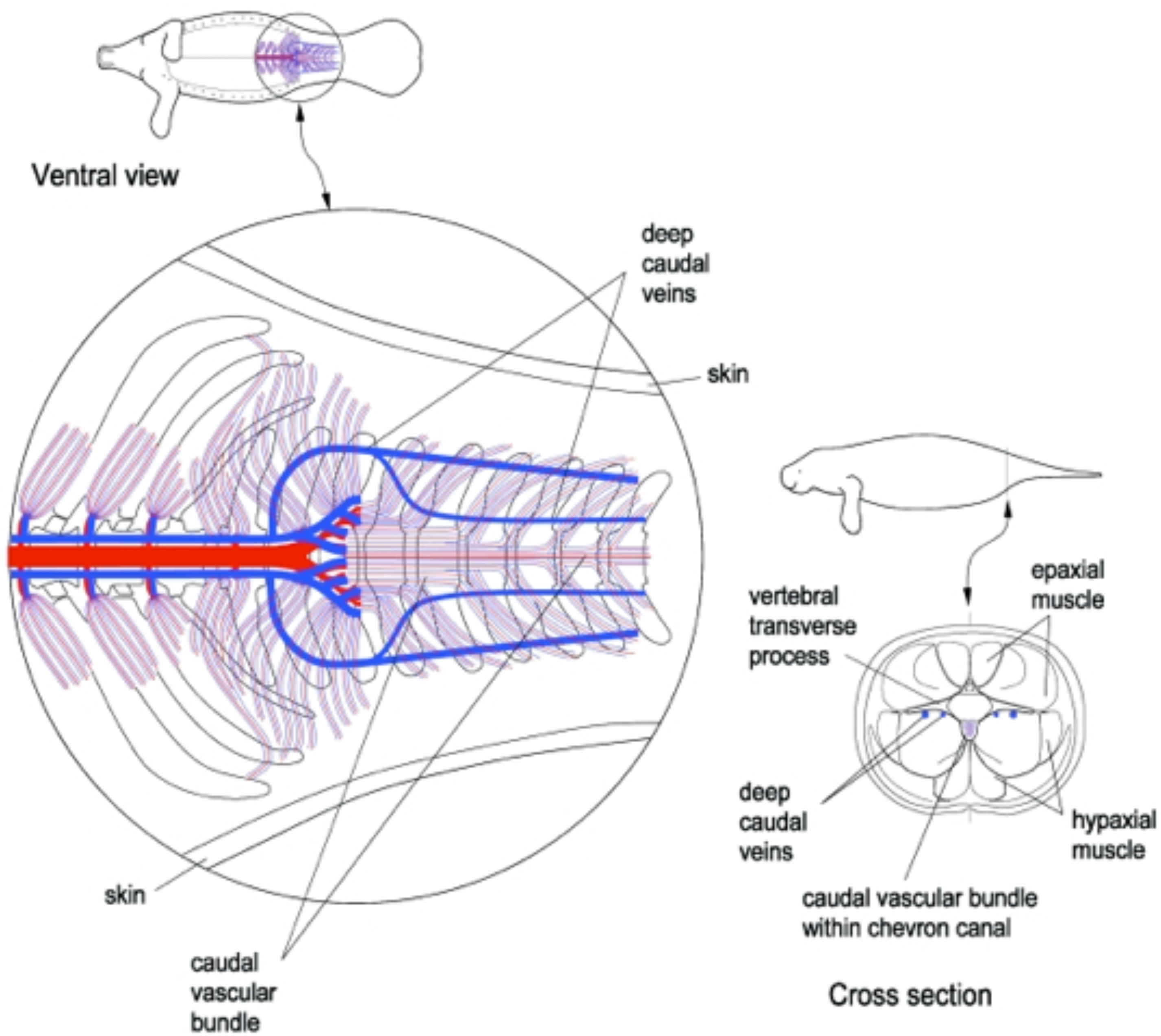


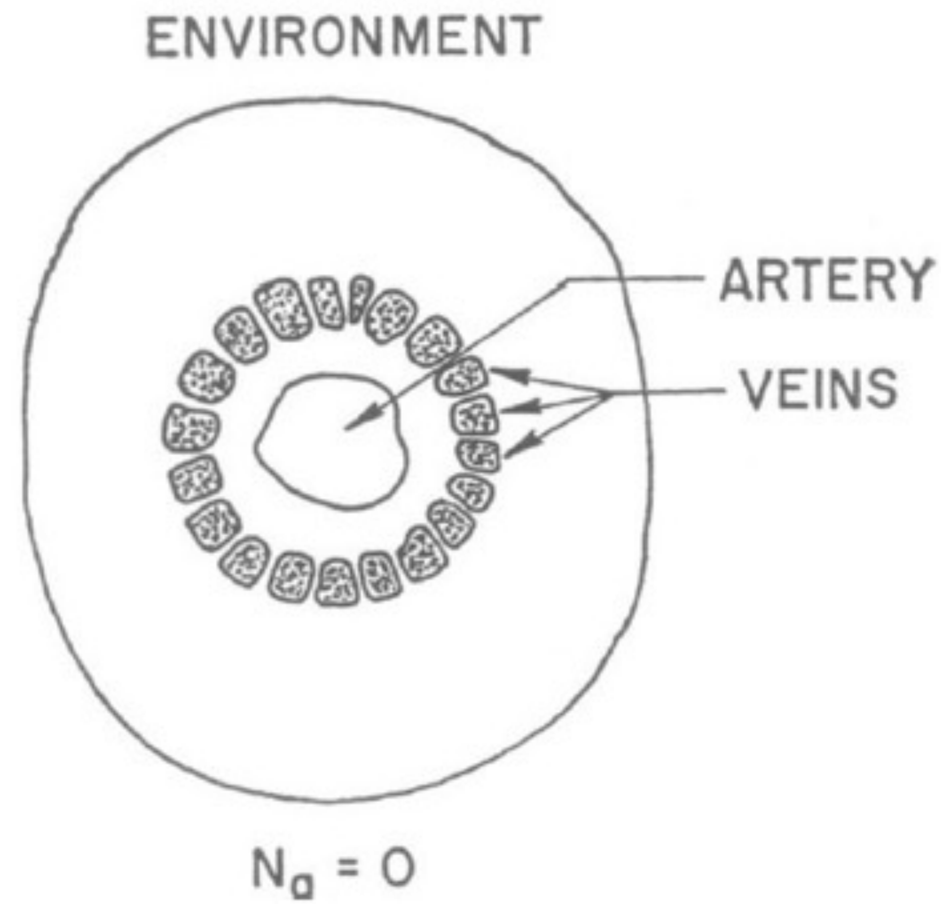
Countercurrent heat exchanger

$$q(x)=h[T_h(x)-T_c(x)]$$



Cocurrent heat exchanger

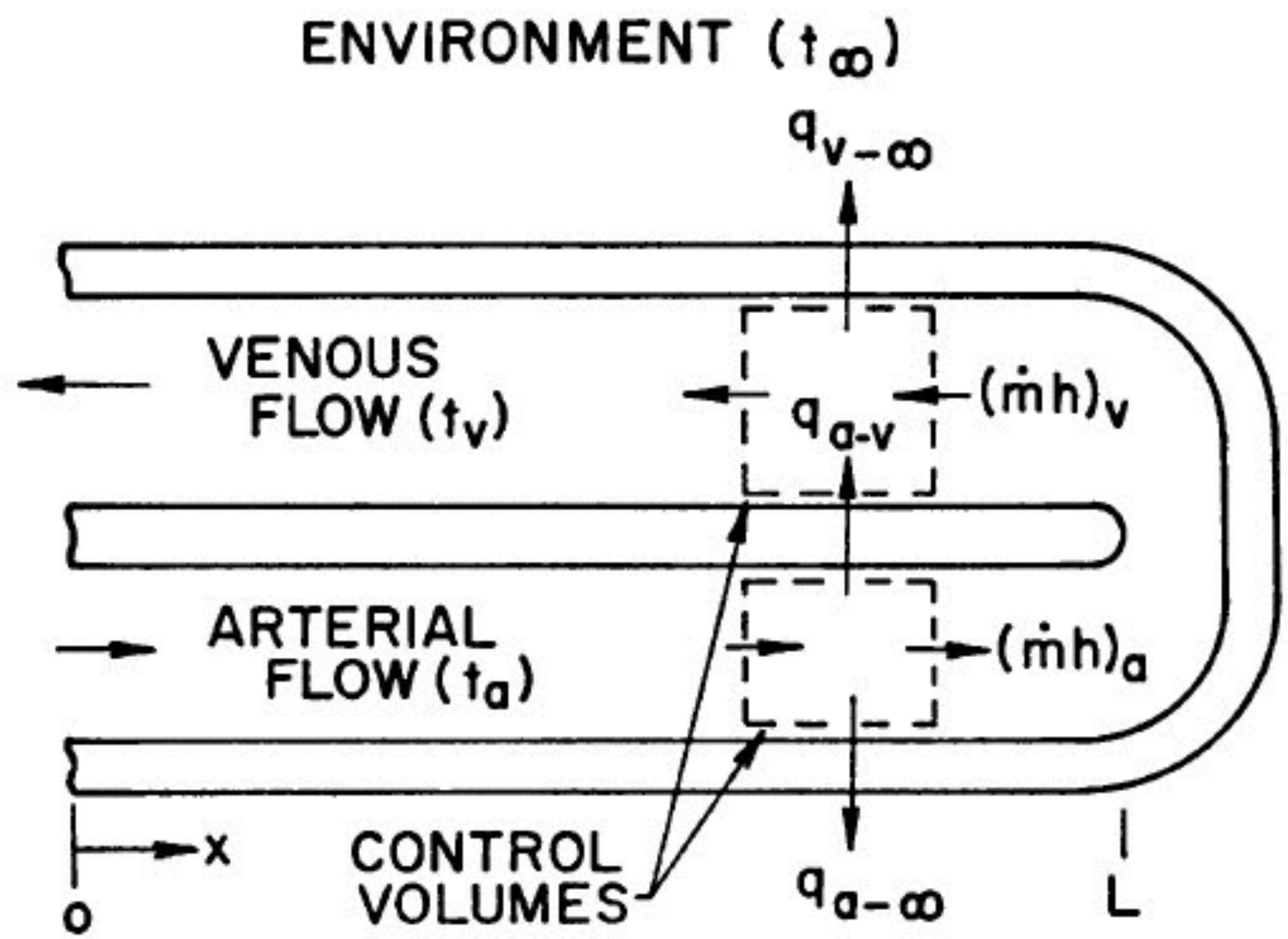


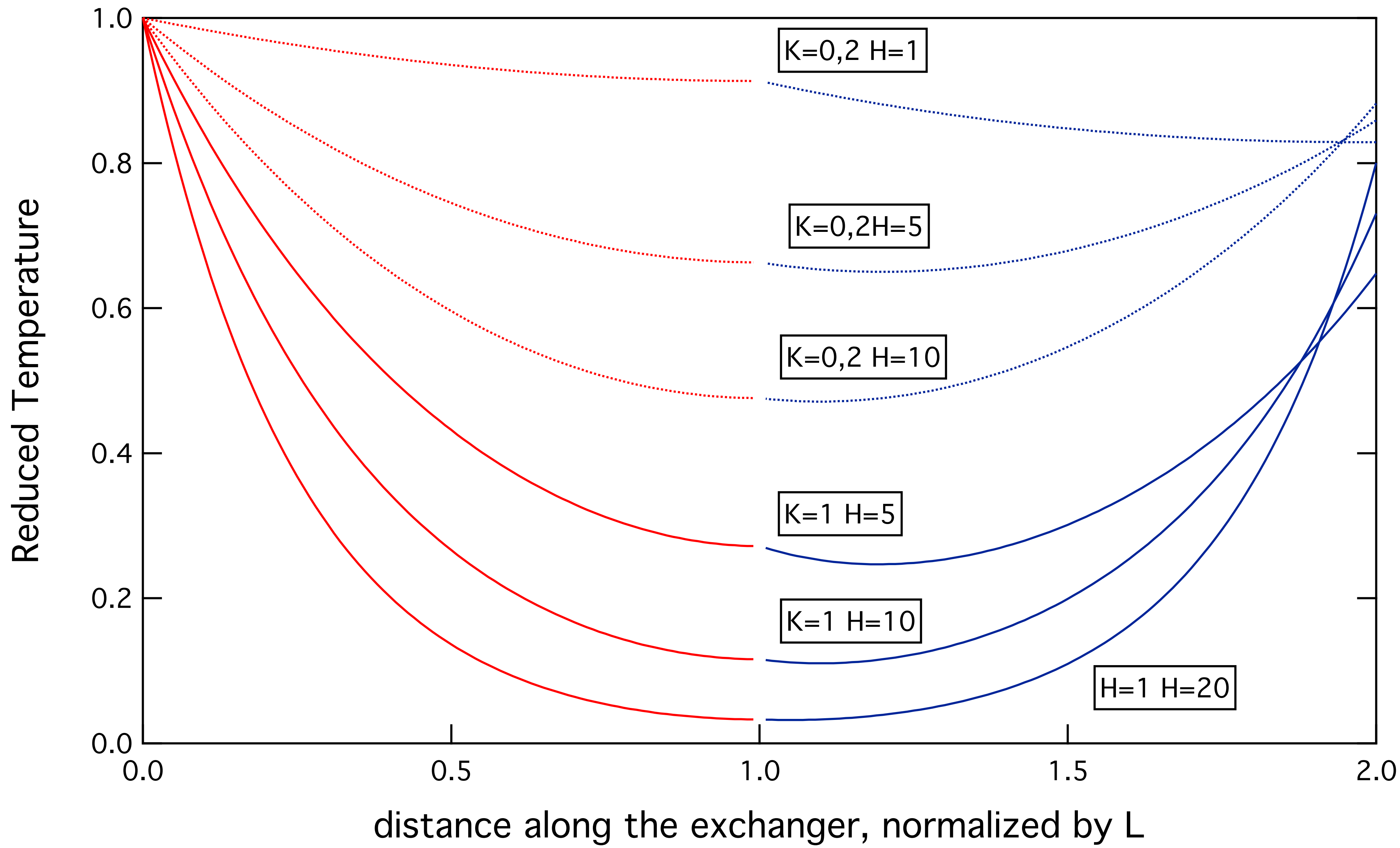


Mitchell & Myers, Biophysical Journal 1968

Rommel & Caplan, Journal of Anatomy 2003

- Write the heat balance within control volumes in the venous flow and the arterial flow
- The arterial flow exchanges only with the venous flow, not with the environment
- Mass flow rates m_a and m_v are equal : m
- Assume heat transfer coefficients h between V and A, k between V and environment
- Write differential equations for $T_A(x)$ and $T_V(x)$



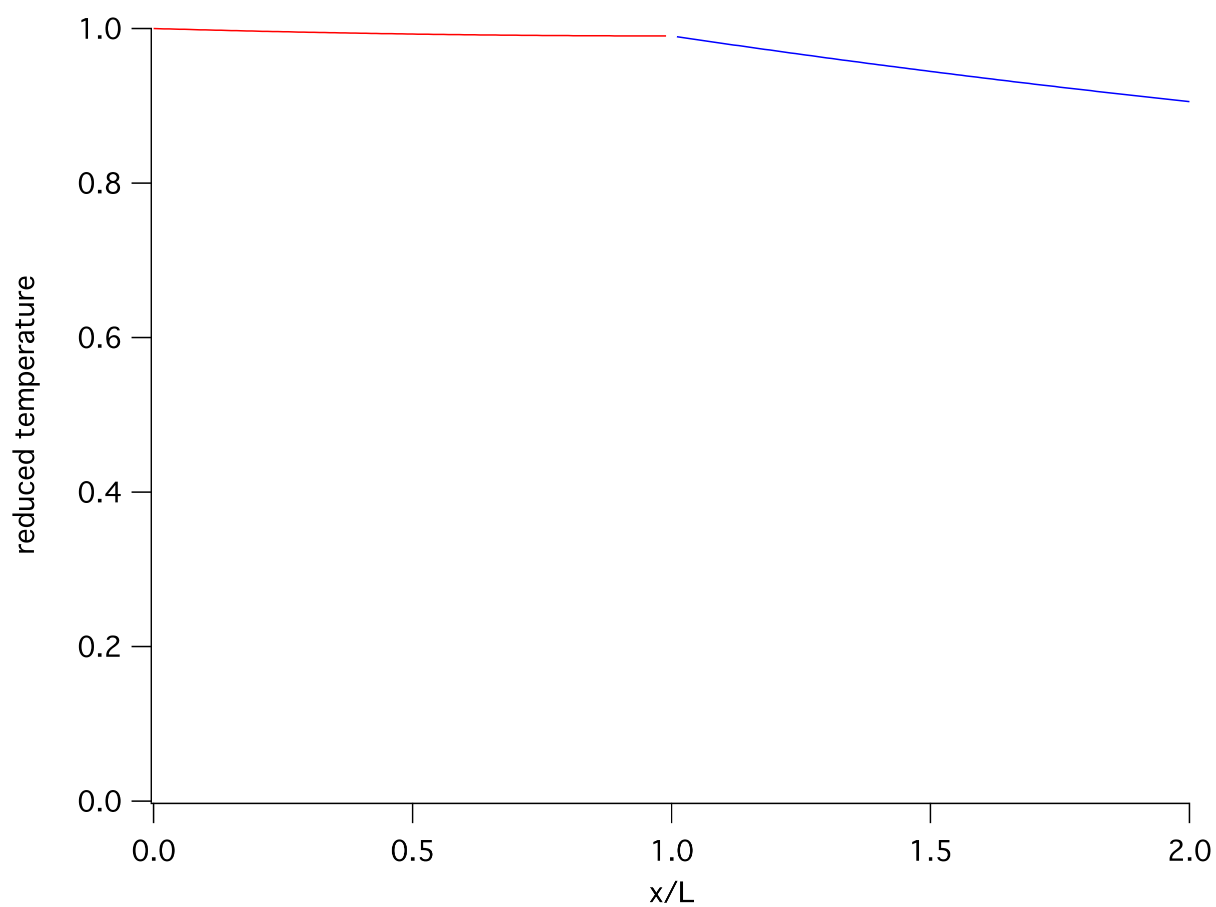


K dimensionless heat flux between the venous flow and the environment
H dimensionless heat flux between the venous flow and the arterial flow

Estimated values for the dimensionless transverse fluxes in a dolphin fin

$$H = h\,L\,/\,m\,C = 0.2$$

$$K = k\,L\,/\,m\,C = 0.1$$



A short summary

In fluids, diffusion is not efficient except at small scales (when Pe << 1)
Within solids, there is no other transport phenomenon

In fluids, at Pe>> 1, convection is dominant, but diffusion cannot be ignored
Transport is accelerated by the creation of thin boundary layers (and enhanced gradients)
Effective fluxes are given by Nusselt or Sherwood numbers
We get scaling laws for Nu or Sh as a function of Pe, Re and Pr
The scaling exponents depend on the particular velocity profile

Thermal convection is specific because heat and momentum transport are strongly coupled
Thermal convection is essentially governed by the Rayleigh number

Radiative heat transfer is governed by Stefan's law
Emissivity = absorptivity
View factors take into account the geometry of radiative surfaces