The enhancement of axial heat and mass transfer by laminar flow oscillation in pipes with axial gradientsin temperature and concentration has been studied analytically for the cases of insulated andconducting walls. The axial diffusivity can exceed its molecular counterpart by many orders of magnitude,with a quadratic scaling on the pressure-gradient amplitude and the Prandtl or Schmidt number,and is a bimodal function of oscillatory frequency: quasi-steady behavior at low frequencies and apower-law decay at high frequencies. When the pipe wall is conductive and of sufficient thickness,and the flow oscillation is quasi-steady, the axial diffusivity may be enhanced by a further factor ofabout ten as a result of increased radial diffusion, for liquid and gas flows in pipes with walls with awide range of thermal conductivities. Criteria for the wall thickness required to achieve this additionalenhancement and for the limits placed on the validity of these solutions by viscous dissipation are alsodeduced. When the heat transfer per unit flow work achieved by oscillatory pipe flow is contrastedwith that of a conventional parallel-flow heat exchanger, it is found to be of comparable size and theratio of the two is shown to be a function only of the pipe geometry, heat-exchanger mean velocity,and fluid viscosity.