The **dry adiabatic lapse rate** (DALR) describes the rate at which the temperature of a parcel of unsaturated (dry) air decreases as it rises in the atmosphere under adiabatic conditions—no heat exchange with the surroundings. It is conventionally given as approximately **9.8 °C/km** (or more precisely ~9.76–9.8 K/km, with the lapse rate defined as the positive value $-dT/dz$).

This value is **not a coincidence** with the acceleration due to gravity **$g \approx 9.8$ m/s²**; it arises directly from the physics of the process. The DALR equals **g / c_p**, where **c_p** is the specific heat capacity of dry air at constant pressure (approximately 1004–1005 J/(kg·K) for Earth's atmosphere).

Derivation (Step by Step)

Consider a parcel of dry air rising in the atmosphere. Two key equations combine here:

1. **Hydrostatic equilibrium** (balance of gravity and pressure gradient in the atmosphere):
   $dP = -\rho g \, dz$
   (Pressure decreases with height dz due to the weight of the air above; ρ is density, g is gravitational acceleration.)
2. **First law of thermodynamics for an adiabatic process** ($dQ = 0$, no heat added or removed):
   The parcel expands as pressure drops, doing work and cooling internally. For dry air treated as an ideal gas, this leads to:
   $c_p \, dT = \alpha \, dP$
   (where $\alpha = 1/\rho$ is the specific volume). More precisely, the enthalpy form simplifies to $c_p \, dT = v \, dP$ (or equivalent after using the ideal gas law).

Combining them (substituting dP from hydrostatic balance into the thermodynamic equation and rearranging):
$dT/dz = -g / c_p$

Thus, the lapse rate $\Gamma\_d = -dT/dz = g / c_p$.

For Earth:

- $g \approx 9.81$ m/s²

- $c_p \approx 1004$ J/(kg·K) = 1004 $m^2/(s^2\cdot K)$ (since 1 J = 1 kg·m^2/s^2, so units simplify cleanly)

Dividing:
$g / c_p \approx 9.81 / 1004 \approx 0.00977$ K/m = **9.77 K/km** (often rounded to 9.8 °C/km, as °C and K differences are identical).

The numerical match with g = 9.8 occurs because c_p for dry air is very close to **1000 J/(kg·K)** (a convenient round number in approximations), and converting from per meter to per kilometer introduces a factor of 1000 that cancels nicely with the ~9.8 / ~1000 ratio. The units work out exactly to K/km (or °C/km) because:

- g has units m/s^2
- c_p has units $m^2/(s^2\cdot K)$
- g / c_p has units K/m → multiply by 1000 for K/km

This relation holds generally for any planetary atmosphere (dry case); the value changes with that planet's g and the c_p of its atmosphere (e.g., it is higher on Venus due to its g and different c_p).

Physical Intuition

- As the air parcel rises, it encounters lower pressure and expands.
- Expansion requires the parcel to do work on its surroundings (pushing neighboring air aside).
- With no heat input (adiabatic), this work comes from the parcel's internal energy → temperature drops.
- The rate depends on how much gravitational potential energy change (tied to g via hydrostatic balance) must be balanced by the cooling needed to maintain the expansion work (tied to c_p, which measures how much temperature change is needed to change the air's energy).

The **moist adiabatic lapse rate** is smaller (typically 4–9 °C/km) because condensation releases latent heat, partially offsetting the cooling.

This 9.8 value is a fundamental consequence of thermodynamics and hydrostatics in a gravitational field—not a coincidence, but a direct outcome where Earth's g and air's c gravitational field—not a coincidence, but a direct outcome where Earth's g and air's c_p happen to produce a clean number.