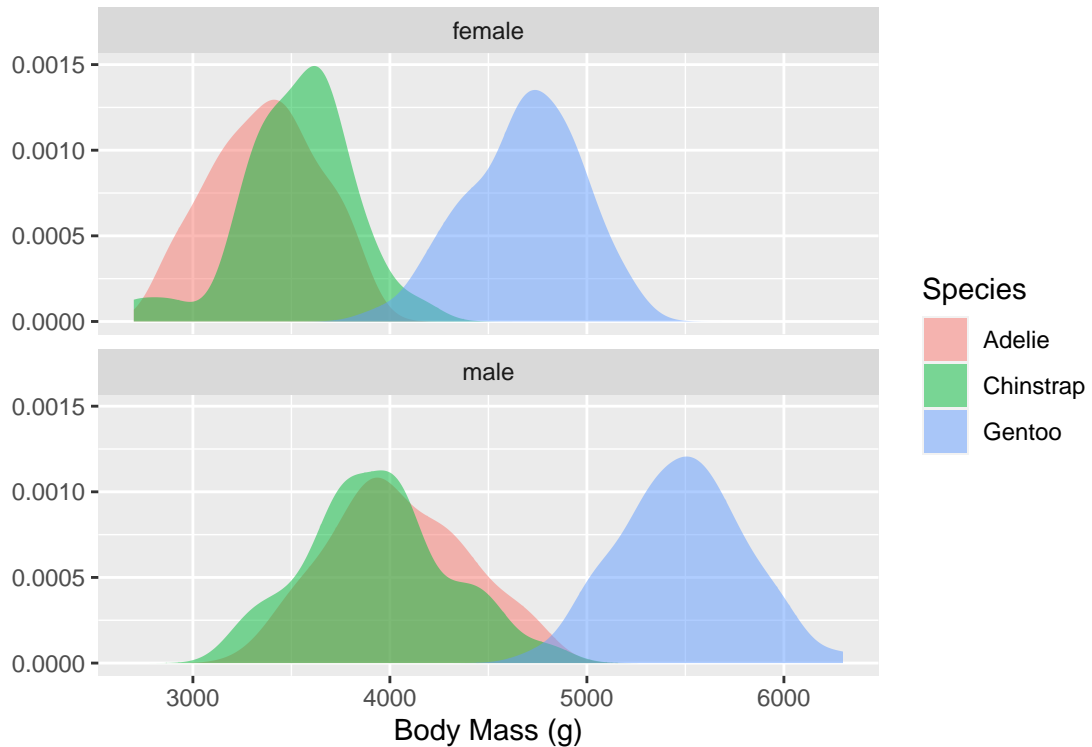


SM-2302 Labs (R4)

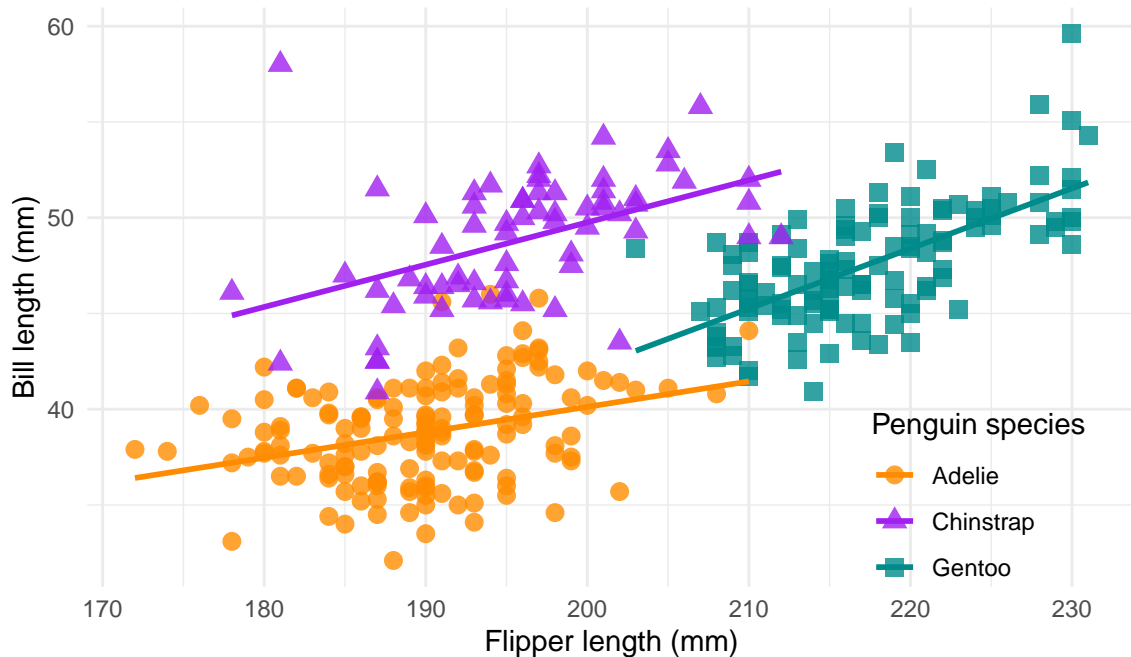
1. Recreate, as faithfully as possible, the following plot using `ggplot2` and the `palmerpenguins::penguins` data.



2. Recreate, as faithfully as possible, the following plot from the `palmerpenguin` package README¹ in `ggplot2`.

Flipper and bill length

Dimensions for Adelie, Chinstrap and Gentoo Penguins at Palmer Station LTER



¹palmerpenguins pkgdown site.

3. How random is a coin flip? In theory, if we knew enough information about the physical system, couldn't we determine exactly the outcome of a coin toss? Consider the following coin flip model.

- A coin flipped with initial vertical velocity v_0 m/s from an initial height h_0 will be, after t seconds, at height

$$h(t) = h_0 + tv_0 - \frac{1}{2}gt^2,$$

where $g = 9.81$ m/s² is the acceleration due to gravity.

- If the coin is caught when it returns to h_0 , the elapsed time t^* satisfies

$$t^* = \frac{2v_0}{g}.$$

- It will have done R number of half-revolutions, where

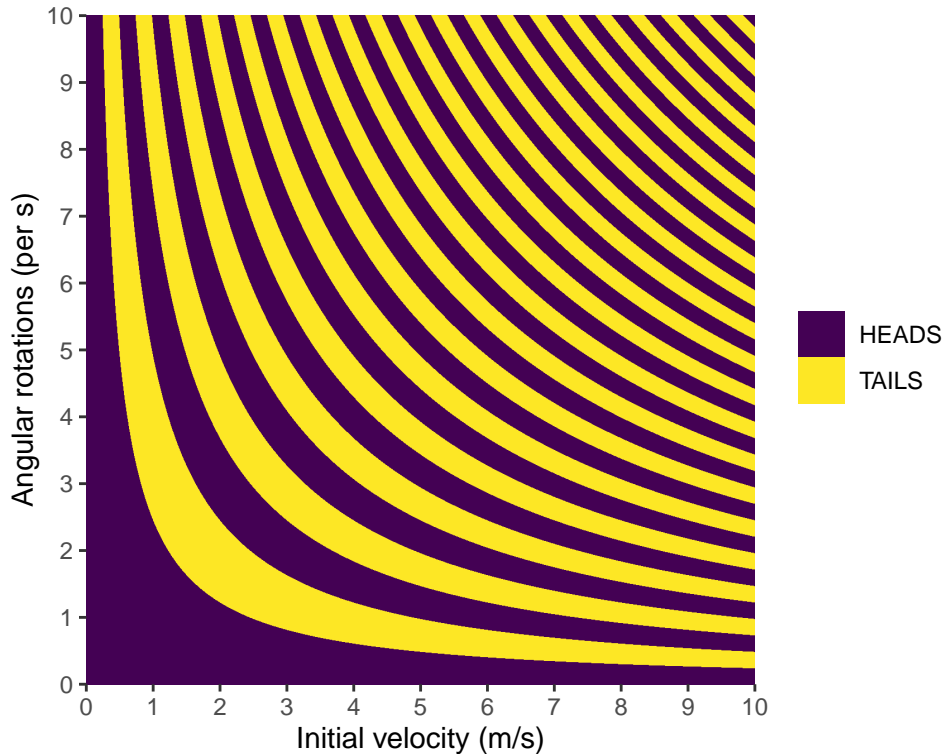
$$R = \omega t^*,$$

and ω is the angular velocity of the coin (measured in revolutions per second).

- Thus, if for some $j \in \mathbb{Z}$, $2j \leq 2R < 2j + 1$ then the initial side will be upmost. If instead $2j + 1 \leq 2R < 2j + 2$, then the opposite side will be upmost.

Therefore, all we need to know is the velocity and angular rotation of the coin flip in order to know whether the coin lands the same or opposite to which it started. As an example, suppose that $\omega = 5$ and $v_0 = 5$, and suppose the coin started out with heads on top. Then, the total elapsed time for this coin flip is $t^* = \frac{2 \times 5}{9.81} = 1.019$ s. This means that the coin revolved $R = 5 \times 1.019 = 5.095$ times, and we notice that $10 \leq 2R < 11$ (choose $j = 5$), indicating that the initial side was upmost (heads).

If we were to tabulate all the results of the coin flip for the range $0 < \omega, v_0 \leq 10$, we would get the following *phase diagram*:



Your task is to recreate, as faithfully as possible, the above phase diagram for a coin flip.