Part 1

Open the African boundaries (`africa_scale.shp`) layer.

1. Compute the centroid of each country, compute a point on the surface of each polygon. Plot both including the boundaries and compare their locations.
2. Do all of these steps in four different CRSs: geographic, Mollweide equal area, Lambert Azimuthal equal area, and Azimuthal equidistant projection.
   - 2.1 Buffer the geographic centroid by either 1 degree or 111 km.
   - 2.2 Compute the area of each buffered centroid in km^2 based on *geographic coordinates*. Why is it more meaningful to calculate these areas in a geographic CRS?
3. Compare the summary statistics of the resulting areas. Is this what you expected?

Part 2

Work through a few geometry operations. In an empty file, clear the work space, load `sf` and then ...

1. Create two points: $P_1 = (0, 1)$ and $P_2 = (1, 1)$. Combine them into a feature collection and buffer each point by one unit. Plot the result with `plot(..., col = 1:2)`.
2. Use `st_intersection()` to calculate the intersection. Add this to the previous plot.
3. Subtract the intersection from the buffered points. You can do this in at least two ways. Do two of them. Plot the result with `plot(..., col = 1:2)`.
4. Calculate the union of the buffered points. What's the difference to the earlier geometry?
5. Does the point $P_3 = (0.5, 0.5)$ intersect with the union of buffers? How about the buffers less their own intersection?

Part 3

We'll examine railways in former British East Africa. Open the African boundaries (`africa_scale.shp`) and African railways (`africa_rail.shp`) layers.

1. British East Africa consisted of Kenya, Tanzania and Uganda. Union the boundaries of these polygons without creating slivers.
2. Compute the total length of railway lines in *km* which fall inside the former British East Africa boundaries. Now compute the total length of railway lines in each of the three countries.
3. Join all of these data to the African boundaries file of the three countries. Plot the share of railways falling inside each of the three countries. Where were most of the railways built?
4. How could you have solved this problem with much less coding?

Part 4

Let's revisit our road density results from earlier. Open the African boundaries (`africa_scale.shp`) and African roads layers (`africa_roads.shp`).

1. Create a grid of 1° cells, starting at (-18, -35) in the lower left.
2. Union the African boundaries without slivers and clip the grid to the boundary of the polygon using `st_intersection()`.
3. Renumber the IDs, so that they run from 1 to N in the new clipped grid. Calculate the area of each cell in km^2.
4. Intersect the roads layer with your grid. Compute the length in *km* of each road in the intersected cells. Calculate the *total* road length in each cell.
5. Join this information back to the grid, calculate the road density in each cell, and the plot the result using `plot(..., breaks="kmeans")`.

Part 5

So far we have snapped broken geometries each time we wanted to create a union without slivers. A more efficient approach might be to fix the underlying geometry once. Open the African boundaries layer (`africa_scale.shp`).

1. Use `table()` to examine if `adm0_a3` is a potentially unique ID.
2. Design a piped workflow to fix the geometries, you will have to project, snap, summarize, join back the original data and project the geometries back to WGS84. Plot to verify.
3. Use `st_is_valid()` and `st_is_simple()` to check whether the geometries are topologically sound.
4. Union the polygons without snapping them and check that everything works sliver free. Write the shapefile to `./data/africa_fixed.shp`.