Question 1 (20 points):

Write a script that:

- Computes the Euclidean distance to another **amenity** of your choosing (HINT: use `gdf['amenity'].unique()` to list the different amenities). Feel free to download OSM buildings from another place and choose a different home' location.
- Makes an interactive map showing where your ten nearest amenities are using `folium`.

In [1]:
```
# Import modules
import osmnx as ox

import numpy as np
import pandas as pd
import geopandas as gpd

from shapely.geometry.polygon import Polygon
from shapely.geometry.multipolygon import MultiPolygon
from shapely.geometry import LineString, MultiLineString
```

In [2]:
```
# Specify type of data
tags = {'building': True}

# Download building geometries from OSM
gdf = ox.geometries_from_place('Eugene, Oregon, USA', tags)
```

```
C:\Users\theoh\anaconda3\envs\lab3\lib\site-packages\osmnx\geometries.py:805: S
hapelyDeprecationWarning: __len__ for multi-part geometries is deprecated and w
ill be removed in Shapely 2.0. Check the length of the `geoms` property instead
to get the  number of parts of a multi-part geometry.
  for merged_outer_linestring in list(merged_outer_linestrings):
C:\Users\theoh\anaconda3\envs\lab3\lib\site-packages\osmnx\geometries.py:805: S
hapelyDeprecationWarning: Iteration over multi-part geometries is deprecated an
d will be removed in Shapely 2.0. Use the `geoms` property to access the consti
tuent parts of a multi-part geometry.
  for merged_outer_linestring in list(merged_outer_linestrings):
```

In [3]:
```
gdf['amenity'].unique()
```

Out[3]:
```
array([nan, 'restaurant', 'fuel', 'fire_station', 'cafe',
       'place_of_worship', 'fast_food', 'library', 'theatre', 'shelter',
       'school', 'bank', 'studio', 'dentist', 'social_facility',
       'training', 'pub', 'college', 'cinema', 'conference_centre',
       'community_centre', 'police', 'parking', 'doctors', 'post_office',
       'clinic', 'bus_station', 'prison', 'courthouse', 'veterinary',
       'music_school', 'bar', 'nightclub', 'car_wash', 'animal_shelter',
       'toilets', 'biergarten', 'childcare', 'recycling', 'marketplace',
       'bicycle_parking', 'arts_centre', 'events_venue', 'social_centre',
       'ice_cream'], dtype=object)
```

In [4]:
```
# Filter restaurants
restaurants = gdf[gdf['amenity'] == 'restaurant'].reset_index()
restaurants
```

Out[4]:

	element_type	osmid	addr:state	building	ele	gnis:county_id	gnis:created	gnis:feature_
0	node	8774901928	OR	yes	NaN	NaN	NaN	N
1	way	122889085	OR	yes	NaN	NaN	NaN	N
2	way	122928477	NaN	yes	NaN	NaN	NaN	N
3	way	216914756	NaN	yes	NaN	NaN	NaN	N
4	way	221398413	NaN	yes	NaN	NaN	NaN	N
...	...	...	...	...	...	...	...	
75	way	875672917	NaN	yes	NaN	NaN	NaN	N
76	way	880839409	NaN	yes	NaN	NaN	NaN	N
77	way	881513126	NaN	yes	NaN	NaN	NaN	N
78	way	912603267	NaN	yes	NaN	NaN	NaN	N
79	way	913689249	NaN	yes	NaN	NaN	NaN	N

80 rows × 230 columns

In [5]:
```
# Reproject to UTM Zone 10N
gdf = gdf.to_crs('EPSG:32610')
restaurants = restaurants.to_crs('EPSG:32610')
```

In [6]:
```
# Get coordinates of The Collegian
collegian = gdf[gdf['name'] == 'The Collegian'].reset_index()
```

In [7]:
```
# Get restaurant and The Collegian centroids
restaurants['centroid'] = restaurants['geometry'].apply(
  lambda x: x.centroid if type(x) == Polygon else (
  x.centroid if type(x) == MultiPolygon else x))

collegian['centroid'] = collegian['geometry'].apply(
  lambda x: x.centroid if type(x) == Polygon else (
  x.centroid if type(x) == MultiPolygon else x))
```

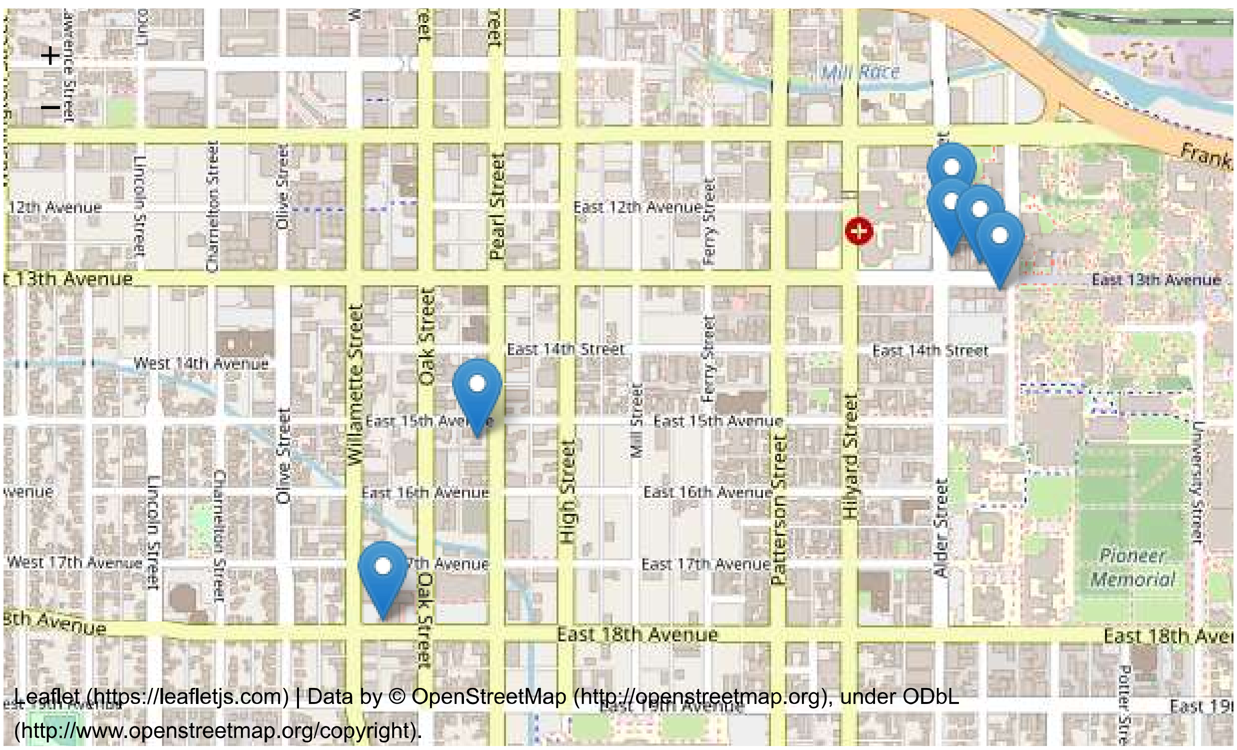
In [8]:
```
# Compute distances
collegian_x = collegian['centroid'].x.values[0]
collegian_y = collegian['centroid'].y.values[0]
distances = np.sqrt(((collegian_x - restaurants['centroid'].x.values)**2)
                     + ((collegian_y - restaurants['centroid'].y.values)**2))

# Add to GeoDataFrame
restaurants['euclidean_distance'] = distances
```

In [9]:
```
print(restaurants.nsmallest(10, ['euclidean_distance'])[['name', 'euclidean_dista
```

```
                                 name  euclidean_distance
12                                NaN          621.795719
14        Caspian Mediterranean Cafe          660.456795
31                      Maple Garden          668.036879
32                Sweet Basil Express          723.693931
66                   Sundance Kitchen          791.078420
55                 Agate Alley Bistro          814.180852
54                    Studio One Cafe          832.271999
48                       Toshi's Ramen          835.596811
49  McMenamins East 19th Street Cafe          851.121521
8                 Hong Kong Restaurant          919.716953
```

In [10]:
```python
# Make a new DataFrame containing only the three most relevant columns
nearest_restaurants = restaurants.nsmallest(10, ['euclidean_distance'])[['name',

# Set column geometry
nearest_restaurants = nearest_restaurants.set_geometry('centroid')

# Convert back to WGS84
nearest_restaurants = nearest_restaurants.to_crs('EPSG:4326')

# Import package
import folium

# Define center of map (i.e. Condon Hall) and initial zoom level
lat_lon = [44.0451, -123.0781]
m = folium.Map(location=lat_lon, zoom_start=15)

for i in range(0, nearest_restaurants.shape[0]):
    my_string = 'name: {}, distance: {}'.format(nearest_restaurants.iloc[i]['name
    folium.Marker([nearest_restaurants.iloc[i]['centroid'].y, nearest_restaurants
                  popup=my_string).add_to(m)

# Display map
m
```

Out[10]:



Computing network distances

Euclidean distances often underestimate the distance between two objects, especially when there are obstacles between the two. So we will now compute some more realistic distances to cafes around Condon Hall. First we will need to import the `networkx` (https://networkx.org/) package which will allow us conduct a network analysis.

Question 2 (20 points):

Adapt the code above to compute the network distance between two points (either in Eugene or in a city of your choice) and show your results using an interactive map. Write a few sentences about what your map shows.

In [11]:
```
# Import module
import networkx as nx
```

In [12]:
```
# Define coordinates of The Collegian
lat_lon = (44.039846, -123.080585)

# Import walkable street network data around The Collegian
g = ox.graph_from_point(lat_lon, dist=1600, network_type='walk')

# Plot map
fig, ax = ox.plot_graph(g, node_size=10)
```

In [13]:
```
# Convert to graph
graph_proj = ox.project_graph(g)

# Get edges and nodes separately
nodes_proj, edges_proj = ox.graph_to_gdfs(graph_proj, nodes=True, edges=True)
```

In [14]:
```
# Check projection is UTM Zone 10N
print("Coordinate system:", edges_proj.crs)

# Convert the restaurant dataset back to UTM Zone 10N
nearest_restaurants = nearest_restaurants.to_crs('EPSG:32610')
```

```
Coordinate system: +proj=utm +zone=10 +ellps=WGS84 +datum=WGS84 +units=m +no_de
fs +type=crs
```

In [15]:
```
# Print list of restaurants to see which desired name is at which index
nearest_restaurants
```

Out[15]:

	name	euclidean_distance	centroid
12	NaN	621.795719	POINT (493676.761 4876907.601)
14	Caspian Mediterranean Cafe	660.456795	POINT (493642.902 4876953.645)
31	Maple Garden	668.036879	POINT (493593.116 4876967.430)
32	Sweet Basil Express	723.693931	POINT (493594.877 4877023.131)
66	Sundance Kitchen	791.078420	POINT (493534.762 4875510.701)
55	Agate Alley Bistro	814.180852	POINT (494347.979 4876232.668)
54	Studio One Cafe	832.271999	POINT (494365.447 4876224.861)
48	Toshi's Ramen	835.596811	POINT (492779.034 4876654.068)
49	McMenamins East 19th Street Cafe	851.121521	POINT (494385.564 4876239.331)
8	Hong Kong Restaurant	919.716953	POINT (492617.971 4876343.601)

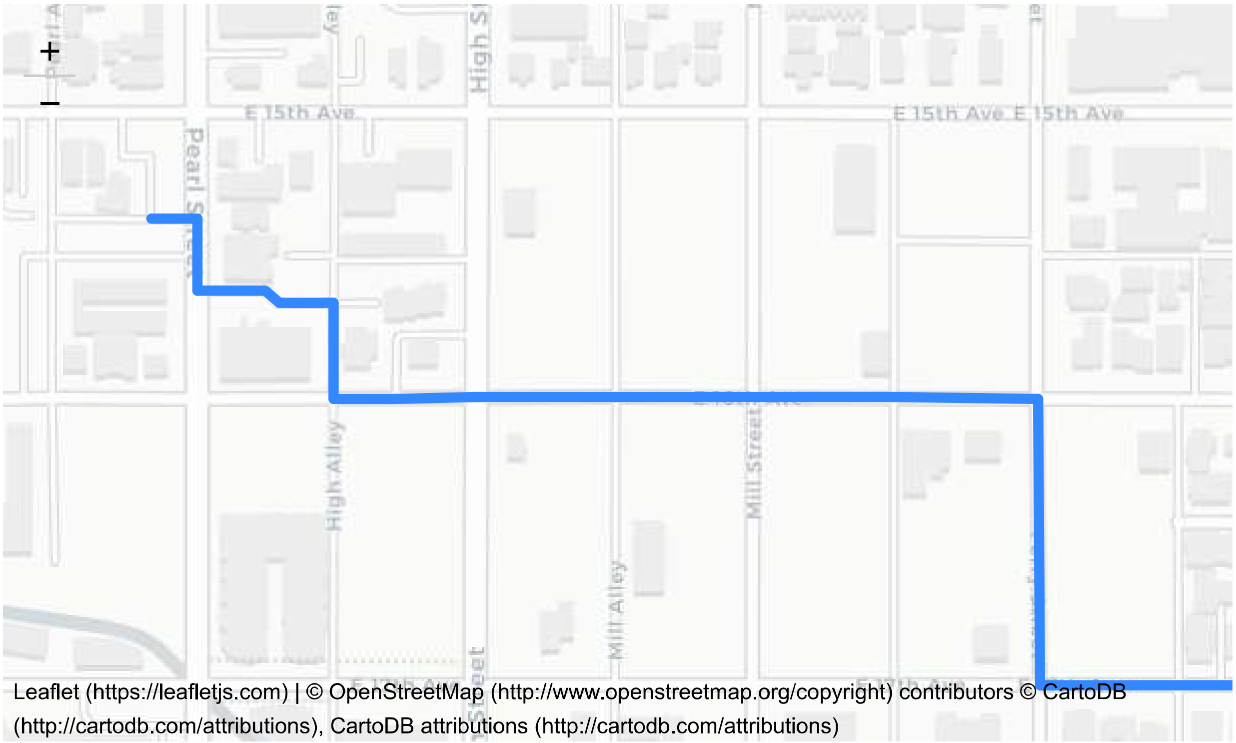
In [16]:
```
# Get x and y coordinates of Condon Hall
orig_xy = (collegian['centroid'].y.values[0], collegian['centroid'].x.values[0])

# Get x and y coordinates of one of Toshi's Ramen (the seventh index)
target_xy = (nearest_restaurants['centroid'].y.values[7], nearest_restaurants['ce
```

In [17]:
```
# Find the node in the graph that is closest to the origin point (here, we want t
orig_node = ox.distance.nearest_nodes(G=graph_proj, X=orig_xy[1], Y=orig_xy[0], r

# Find the node in the graph that is closest to the target point (here, we want t
target_node = ox.distance.nearest_nodes(graph_proj, X=target_xy[1], Y=target_xy[0
```

In [18]:
```
# Calculate the shortest path
route = nx.shortest_path(G=graph_proj, source=orig_node, target=target_node, weig
```

In [19]:
```
# Plot the shortest path using folium
m = ox.plot_route_folium(g, route, weight=5)
m
```

Out[19]:



The above map shows the shortest route from **The Collegian** (bottom right) to **Toshi's Ramen** (upper left) in Eugene, OR.

Compute network distances between The Collegian and restaurants

In [20]:
```
# Get x and y coordinates of all ten of the nearest restaurants
target_xy = (nearest_restaurants['centroid'].y.values, nearest_restaurants['centr
```

In [21]:
```
routes = []
distances = []
for i in range(len(target_xy[0])):

    # Find the node in the graph that is closest to the target point (here, we wo
    target_node = ox.distance.nearest_nodes(graph_proj, X=target_xy[1][i], Y=targ

    # Calculate the shortest path
    route = nx.shortest_path(G=graph_proj, source=orig_node, target=target_node, 

    # Append route to list
    routes.append(route)

    # Get the nodes along the shortest path
    route_nodes = nodes_proj.loc[route]

    # Create a geometry for the shortest path
    route_line = LineString(list(route_nodes['geometry'].values))

    # Create a GeoDataFrame
    route_geom = gpd.GeoDataFrame([[route_line]], geometry='geometry', crs=edges_

    # Print length of route
    print('Walking distance to %s = %.1f km' % (nearest_restaurants['name'].iloc[

    # Append distances to list
    distances.append(route_geom['geometry'].length[0])
```

```
Walking distance to nan = 0.8 km
Walking distance to Caspian Mediterranean Cafe = 0.8 km
Walking distance to Maple Garden = 0.7 km
Walking distance to Sweet Basil Express = 0.8 km
Walking distance to Sundance Kitchen = 0.9 km
Walking distance to Agate Alley Bistro = 0.9 km
Walking distance to Studio One Cafe = 1.0 km
Walking distance to Toshi's Ramen = 1.0 km
Walking distance to McMenamins East 19th Street Cafe = 1.0 km
Walking distance to Hong Kong Restaurant = 0.9 km
```

In [22]:
```
nearest_restaurants['network_distance'] = distances
nearest_restaurants
```

Out[22]:

	name	euclidean_distance	centroid	network_distance
12	NaN	621.795719	POINT (493676.761 4876907.601)	755.791684
14	Caspian Mediterranean Cafe	660.456795	POINT (493642.902 4876953.645)	816.562847
31	Maple Garden	668.036879	POINT (493593.116 4876967.430)	737.681065
32	Sweet Basil Express	723.693931	POINT (493594.877 4877023.131)	761.964456
66	Sundance Kitchen	791.078420	POINT (493534.762 4875510.701)	872.253689
55	Agate Alley Bistro	814.180852	POINT (494347.979 4876232.668)	891.510994
54	Studio One Cafe	832.271999	POINT (494365.447 4876224.861)	1038.154627
48	Toshi's Ramen	835.596811	POINT (492779.034 4876654.068)	1033.834211
49	McMenamins East 19th Street Cafe	851.121521	POINT (494385.564 4876239.331)	1038.154627
8	Hong Kong Restaurant	919.716953	POINT (492617.971 4876343.601)	902.542253

Question 3 (10 points):

- a) Calculate the average difference between the Euclidean and network distances for you amenities
- b) Describe some situations where it would not be advisable to use Euclidean distances?

Part a

In [23]:
```
# Retrieve all euclidean and network distances
euc_dist = nearest_restaurants['euclidean_distance'].tolist()
net_dist = nearest_restaurants['network_distance'].tolist()
```

In [24]:
```
# Loop over each distance to calculate average difference
differences = []
for i in range(len(euc_dist)):
    differences.append((abs(euc_dist[i] - net_dist[i])))
```

In [25]:
```
# Find average of all distances
avg = sum(differences)/len(differences)
avg
```

Out[25]:
```
116.48499750201714
```

Part b

For the most part, any type of distance analysis that requires the use of a road network should avoid using euclidean distance.

This is because many obstructions can heavily influence the required path between two nodes and therefore alter the distance that is travelled between nodes.

For example, in a situation where someone wants to know the distance to the closest library, this would require the use of a road network to reach the destination. If that this person lived on the other side of a major highway as the closest library and therefore had to take a detour to the nearest overpass for that highway before reaching the library, this would heavily influence the distance travelled when compared to the euclidean straight line distance.