Assignment 5

Due at 11:59pm on November 26.

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You may work in pairs or individually for this assignment. Make sure you join a group in Canvas if you are working in pairs. Turn in this assignment as an HTML or PDF file to ELMS. Make sure to include the R Markdown or Quarto file that was used to generate it. Include the GitHub link for the repository containing these files.

GitHub link: https://github.com/mollyfischfriedman/FischFriedman-Owen-a5

```
library(censusapi)
```

```
Attaching package: 'censusapi'

The following object is masked from 'package:methods':

    getFunction
```

```
library(tidyverse)
```

```
-- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
v dplyr     1.1.4     v readr     2.1.5
v forcats   1.0.0     v stringr   1.5.1
v ggplot2   3.4.2     v tibble    3.2.1
v lubridate 1.9.3     v tidyr     1.3.1
v purrr     1.0.2
```

```
-- Conflicts ---------------------------------------- tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to becor
```

```
library(magrittr)
```

```
Attaching package: 'magrittr'

The following object is masked from 'package:purrr':

    set_names

The following object is masked from 'package:tidyr':

    extract
```

```
library(factoextra)
```

```
Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
library(cluster)
library(factoextra)
```

Exploring ACS Data

In this notebook, we use the Census API to gather data from the American Community Survey (ACS). This requires an access key, which can be obtained here:

https://api.census.gov/data/key_signup.html

```
cs_key <- read_file("~/Downloads/census-key.txt")
acs_il_c <- getCensus(name = "acs/acs5",
                      vintage = 2016,
                      vars = c("NAME", "B01003_001E", "B19013_001E", "B19301_001E"),
                      region = "county:*",
                      regionin = "state:17",
                      key = cs_key) %>%
            rename(pop = B01003_001E,
```

```
                    hh_income = B19013_001E,
                    income = B19301_001E)
head(acs_il_c)
```

```
  state county                        NAME    pop hh_income income
1    17    067   Hancock County, Illinois  18633     50077  25647
2    17    063    Grundy County, Illinois  50338     67162  30232
3    17    091  Kankakee County, Illinois 111493     54697  25111
4    17    043    DuPage County, Illinois 930514     81521  40547
5    17    003 Alexander County, Illinois   7051     29071  16067
6    17    129    Menard County, Illinois  12576     60420  31323
```

Pull map data for Illinois into a data frame.

```
il_map <- map_data("county", region = "illinois")
head(il_map)
```

```
       long      lat group order   region subregion
1 -91.49563 40.21018     1     1 illinois     adams
2 -90.91121 40.19299     1     2 illinois     adams
3 -90.91121 40.19299     1     3 illinois     adams
4 -90.91121 40.10704     1     4 illinois     adams
5 -90.91121 39.83775     1     5 illinois     adams
6 -90.91694 39.75754     1     6 illinois     adams
```

Join the ACS data with the map data. Not that `il_map` has a column `subregion` which includes county names. We need a corresponding variable in the ACS data to join both data sets. This needs some transformations, among which the function `tolower()` might be useful. Call the joined data `acs_map`.

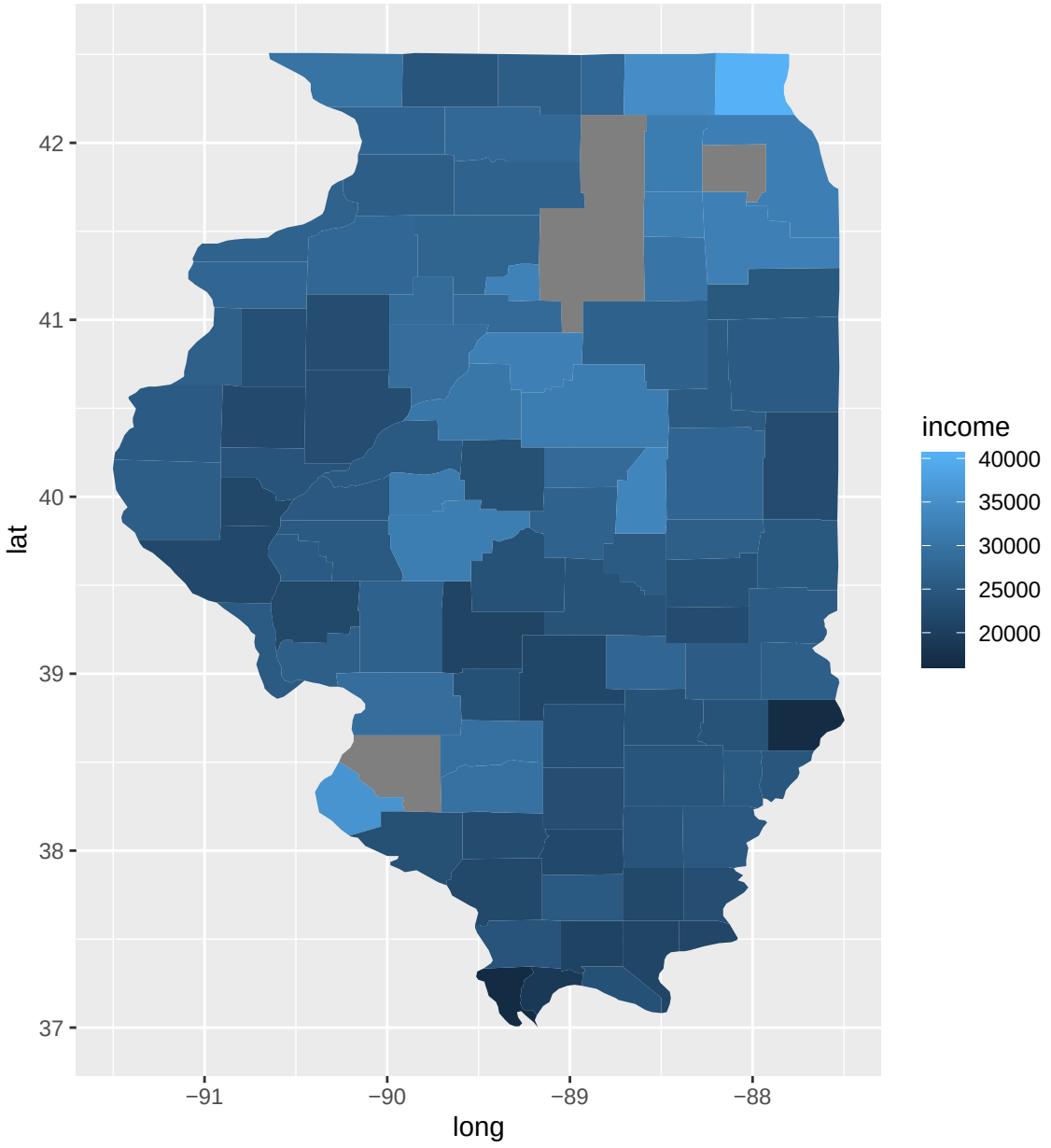
```
acs_il_c$subregion <- tolower(gsub("\\sCounty.+","",acs_il_c$NAME))
acs_map <- left_join(il_map, acs_il_c, by="subregion")
head(acs_map)
```

```
       long      lat group order   region subregion state county
1 -91.49563 40.21018     1     1 illinois     adams    17    001
2 -90.91121 40.19299     1     2 illinois     adams    17    001
3 -90.91121 40.19299     1     3 illinois     adams    17    001
4 -90.91121 40.10704     1     4 illinois     adams    17    001
5 -90.91121 39.83775     1     5 illinois     adams    17    001
```

```
6 -90.91694 39.75754     1     6 illinois     adams    17    001
                    NAME   pop hh_income income
1 Adams County, Illinois 66949     48065  26053
2 Adams County, Illinois 66949     48065  26053
3 Adams County, Illinois 66949     48065  26053
4 Adams County, Illinois 66949     48065  26053
5 Adams County, Illinois 66949     48065  26053
6 Adams County, Illinois 66949     48065  26053
```

After you do this, plot a map of Illinois with Counties colored by per capita income.

```
ggplot(acs_map) + geom_polygon(aes(x = long, y = lat, group = group, fill = income))
```



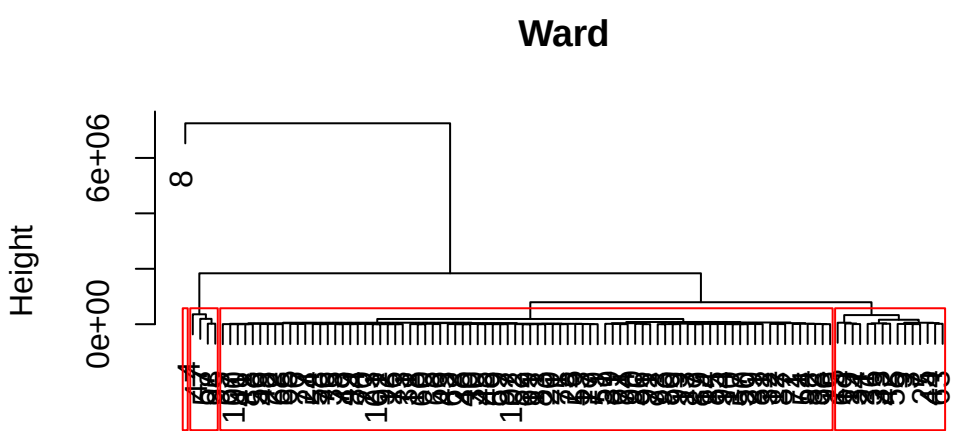
Hierarchical Clustering

We want to find clusters of counties that are similar in their population, average household income and per capita income. First, clean the data so that you have the appropriate variables to use for clustering. Next, create the distance matrix of the cleaned data. This distance matrix can be used to cluster counties, e.g. using the ward method.

```
hclust <- acs_il_c %>% select(pop, hh_income, income)
hclust_dist <- dist(hclust)
hc_ward <- hclust(hclust_dist, method = "ward.D2")
```

Plot the dendrogram to find a reasonable number of clusters. Draw boxes around the clusters of your cluster solution.

```
plot(hc_ward, main = "Ward", xlab = "", sub = "")
rect.hclust(hc_ward,
            k = 4,
            border = "red")
```



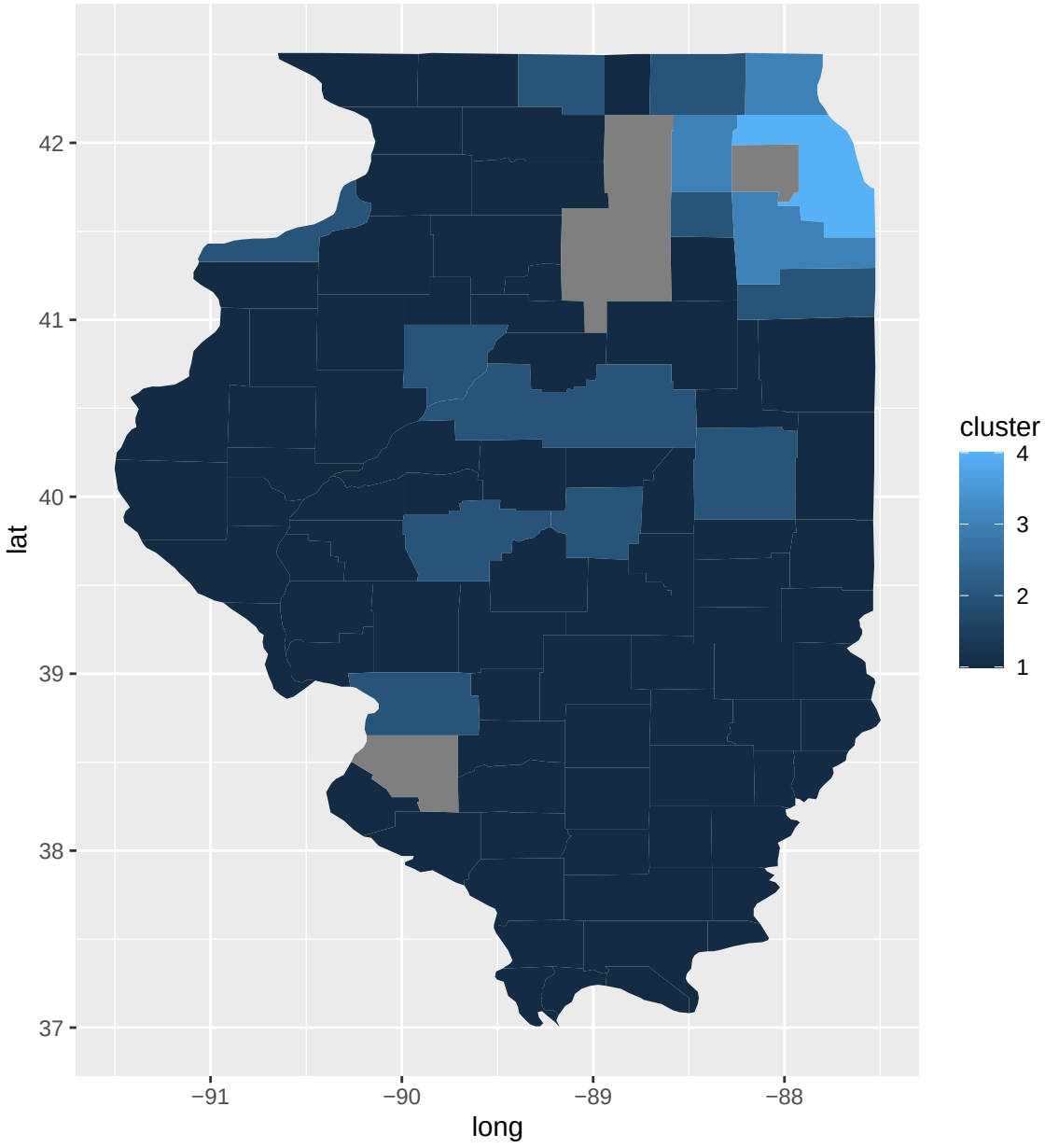
Visualize the county clusters on a map. For this task, create a new `acs_map` object that now also includes cluster membership as a new column. This column should be called `cluster`.

```
cluster <- cutree(hc_ward, 4)
acs_il_c$cluster <- cluster
acs_map <- left_join(il_map, acs_il_c, by="subregion")
head(acs_map)
```

```
       long      lat group order   region subregion state county
1 -91.49563 40.21018     1     1 illinois     adams    17    001
```

```
2 -90.91121 40.19299     1     2 illinois     adams    17    001
3 -90.91121 40.19299     1     3 illinois     adams    17    001
4 -90.91121 40.10704     1     4 illinois     adams    17    001
5 -90.91121 39.83775     1     5 illinois     adams    17    001
6 -90.91694 39.75754     1     6 illinois     adams    17    001
                    NAME   pop hh_income income cluster
1 Adams County, Illinois 66949     48065  26053       1
2 Adams County, Illinois 66949     48065  26053       1
3 Adams County, Illinois 66949     48065  26053       1
4 Adams County, Illinois 66949     48065  26053       1
5 Adams County, Illinois 66949     48065  26053       1
6 Adams County, Illinois 66949     48065  26053       1
```

```
ggplot(acs_map) + geom_polygon(aes(x = long, y = lat, group = group, fill = cluster))
```



Census Tracts

For the next section we need ACS data on a census tract level. We use the same variables as before.

```
acs_il_t <- getCensus(name = "acs/acs5",
                      vintage = 2016,
                      vars = c("NAME", "B01003_001E", "B19013_001E", "B19301_001E"),
                      region = "tract:*",
                      regionin = "state:17",
                      key = cs_key) %>%
             rename(pop = B01003_001E,
                    hh_income = B19013_001E,
                    income = B19301_001E)

head(acs_il_t)
```

```
  state county  tract                                          NAME  pop
1    17    031 806002 Census Tract 8060.02, Cook County, Illinois 7304
2    17    031 806003 Census Tract 8060.03, Cook County, Illinois 7577
3    17    031 806400    Census Tract 8064, Cook County, Illinois 2684
4    17    031 806501 Census Tract 8065.01, Cook County, Illinois 2590
5    17    031 750600    Census Tract 7506, Cook County, Illinois 3594
6    17    031 310200    Census Tract 3102, Cook County, Illinois 1521
  hh_income income
1     56975  23750
2     53769  25016
3     62750  30154
4     53583  20282
5     40125  18347
6     63250  31403
```

```
#saving Rda files
save(acs_il_c, file="~/Downloads/acs_il_c.Rda")
save(acs_il_t, file="~/Downloads/acs_il_t.Rda")
save(acs_map, file="~/Downloads/acs_map.Rda")
```

k-Means

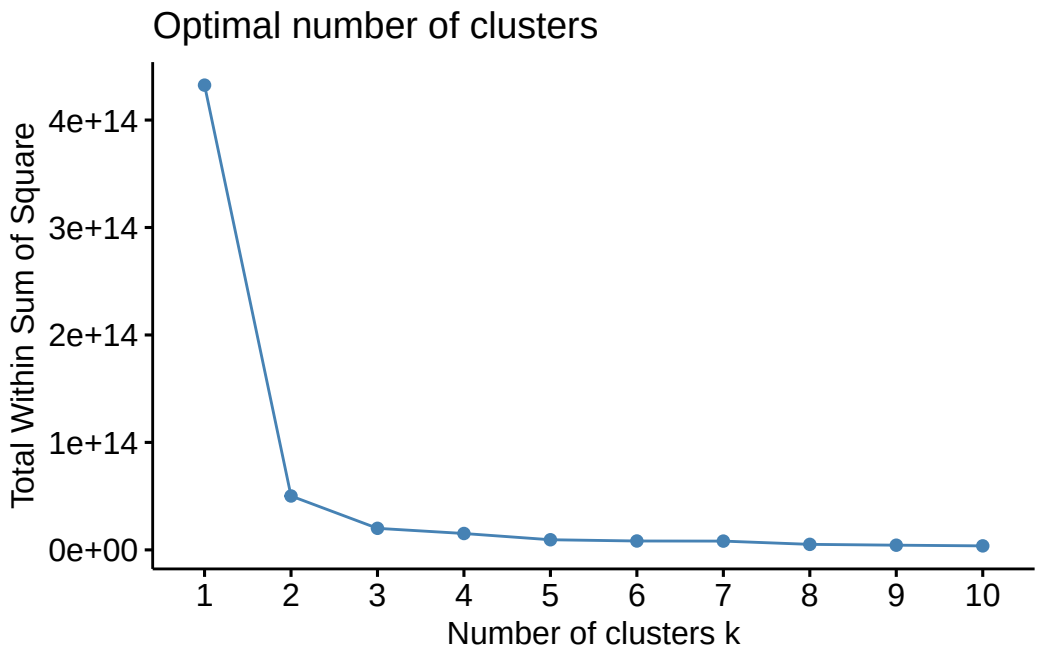
As before, clean our data for clustering census tracts based on population, average household income and per capita income.

```
tclust <- acs_il_t %>% select(pop, hh_income, income, tract, county, state)
tclust_dist <- dist(tclust)

tclust[tclust == -666666666] <- NA
```

Since we want to use K Means in this section, we start by determining the optimal number of K that results in Clusters with low within but high between variation. Plot within cluster sums of squares for a range of K (e.g. up to 20).

```
fviz_nbclust(na.omit(tclust), kmeans, method = "wss")
```



Run `kmeans()` for the optimal number of clusters based on the plot above.

```
km_1 <- kmeans(na.omit(tclust), 2, nstart = 20)
km_1
```

```
K-means clustering with 2 clusters of sizes 1918, 1191

Cluster means:
       pop hh_income   income    tract   county state
1 4341.583  66127.53 31116.94 826445.3 72.18457    17
2 3789.817  53196.33 29850.75 105177.8 87.00336    17

Clustering vector:
   1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16
   1    1    1    1    1    2    1    1    1    1    1    1    1    1    1    1
  17   18   19   20   21   22   23   24   25   26   27   28   29   30   31   32
```

1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1
65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
2	2	1	1	1	2	2	1	1	1	1	1	1	1	1	1
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2
161	162	163	164	165	166	167	168	169	170	171	172	173	175	176	177
2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193
2	2	2	2	2	2	2	2	1	2	2	2	1	1	1	2
194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209
1	1	1	1	1	2	1	1	1	1	1	2	2	2	1	1
210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1
226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241
1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2
242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273
2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305
1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337
1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369
1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1

370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385
1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	1
386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401
1	1	2	1	1	1	2	2	2	2	2	2	2	2	2	2
402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417
2	2	2	1	1	2	2	2	2	2	1	1	1	2	2	2
418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433
2	2	1	1	1	1	1	2	2	2	2	2	1	1	1	2
434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449
2	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
450	451	452	453	454	455	456	457	458	459	460	461	462	464	465	466
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482
2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530
1	1	1	1	1	1	1	1	1	1	2	2	1	1	2	2
531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546
2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610
1	1	1	1	1	1	2	2	2	2	2	1	1	1	1	2
611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642
2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658
1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	2
659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690
1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706
2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738
1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
739	741	742	743	744	746	747	748	749	750	751	752	753	754	755	756
1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1
757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
773	774	775	776	777	778	779	780	782	783	784	785	786	787	788	789
1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2
790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
806	807	808	809	810	811	812	813	815	816	817	818	819	820	821	822
2	2	2	2	2	2	2	1	2	1	1	1	2	1	1	1
823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838
2	2	2	1	1	1	1	1	1	2	2	1	1	1	1	1
839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886
1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902
2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918
1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1
919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934
1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1
935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966
1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1
967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062
1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2

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1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948
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2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669
1	1	1	1	2	2	2	2	2	2	2	1	1	2	2	2
2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685
2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717
1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765
1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781
2	2	2	1	1	1	1	1	2	1	1	1	1	2	2	1
2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797

1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	1
2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813
1	1	1	1	1	2	2	2	2	2	2	1	1	1	2	1
2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829
2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845
1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925
2	2	2	1	1	1	2	2	2	2	2	2	1	1	1	2
2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957
2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2
2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973
2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989
1	1	2	2	2	2	2	1	1	1	1	1	1	1	1	1
2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3006	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022
1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
3023	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038
2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
3039	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3055	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070
2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
3071	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086
1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102
2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
3103	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118
1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
3119	3120	3121	3122	3123											
2	2	2	2	2											

```
Within cluster sum of squares by cluster:
[1] 2.541980e+13 2.471886e+13
 (between_SS / total_SS =  88.4 %)

Available components:

[1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
[6] "betweenss"    "size"         "iter"         "ifault"
```

Find the mean population, household income and per capita income grouped by clusters. In addition, display the most frequent county that can be observed within each cluster.

```
tclust$cluster[which(!is.na(tclust$hh_income))] <- km_1$cluster

tclust %>%
  filter(cluster==1) %>%
  summarise(mean_pop=mean(pop),
            mean_hh_income=mean(hh_income),
            mean_income=mean(income),
            most_freq_county=names(sort(-table(tclust$county)))[1])
```

```
  mean_pop mean_hh_income mean_income most_freq_county
1 4341.583       66127.53    31116.94              031
```

```
tclust %>%
  filter(cluster==2) %>%
  summarise(mean_pop=mean(pop),
            mean_hh_income=mean(hh_income),
            mean_income=mean(income),
            most_freq_county=names(sort(-table(tclust$county)))[1])
```

```
  mean_pop mean_hh_income mean_income most_freq_county
1 3789.817       53196.33    29850.75              031
```

As you might have seen earlier, it's not always clear which number of clusters is the optimal choice. To automate K Means clustering, program a function based on `kmeans()` that takes K as an argument. You can fix the other arguments, e.g. such that a specific dataset is always used when calling the function.

```r
kfunction <- function(k){
  kmeans(na.omit(tclust), k)
}
```

We want to utilize this function to iterate over multiple Ks (e.g., K = 2, ..., 10) and – each time – add the resulting cluster membership as a new variable to our (cleaned) original data frame (`acs_il_t`). There are multiple solutions for this task, e.g. think about the `apply` family or `for` loops.

```r
kfunction2 <- function(k){
  km <- kfunction(k)
  new_column <- paste0("cluster_", k)
  acs_il_t[[new_column]] <- NA
  acs_il_t[[new_column]][which(!is.na(tclust$hh_income))] <- km$cluster
  return(acs_il_t)
}

for (i in seq(2, 10, by=2)) {
  acs_il_t <- kfunction2(i)
}
```

Finally, display the first rows of the updated data set (with multiple cluster columns).

```r
head(acs_il_t)
```

```
  state county  tract                                         NAME  pop
1    17    031 806002 Census Tract 8060.02, Cook County, Illinois 7304
2    17    031 806003 Census Tract 8060.03, Cook County, Illinois 7577
3    17    031 806400    Census Tract 8064, Cook County, Illinois 2684
4    17    031 806501 Census Tract 8065.01, Cook County, Illinois 2590
5    17    031 750600    Census Tract 7506, Cook County, Illinois 3594
6    17    031 310200    Census Tract 3102, Cook County, Illinois 1521
  hh_income income cluster_2 cluster_4 cluster_6 cluster_8 cluster_10
1     56975  23750         1         2         4         4          5
2     53769  25016         1         2         4         4          5
3     62750  30154         1         2         4         4          5
4     53583  20282         1         2         4         4          5
5     40125  18347         1         2         4         4          5
6     63250  31403         2         3         2         6          4
```