

Lecture 2: Data Frame, Matrix, List

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Preamble

Practice makes perfect

- Start using RSeek
- Other resources on website
http://www.araastat.com/BIOF339_PracticalR
- Beg, Borrow, Steal code that you need
 - R is open-source, so is meant to be shared

R coding conventions

```
# This is a comment, which doesn't get evaluated  
1:3 # This is also a comment
```

```
## [1] 1 2 3
```

```
# Multi-line code  
  
x <- c(1, 2,  
      3, 4, 5, 6,  
      7)  
x
```

```
## [1] 1 2 3 4 5 6 7
```

Google has a [style guide](#) for how to write R code

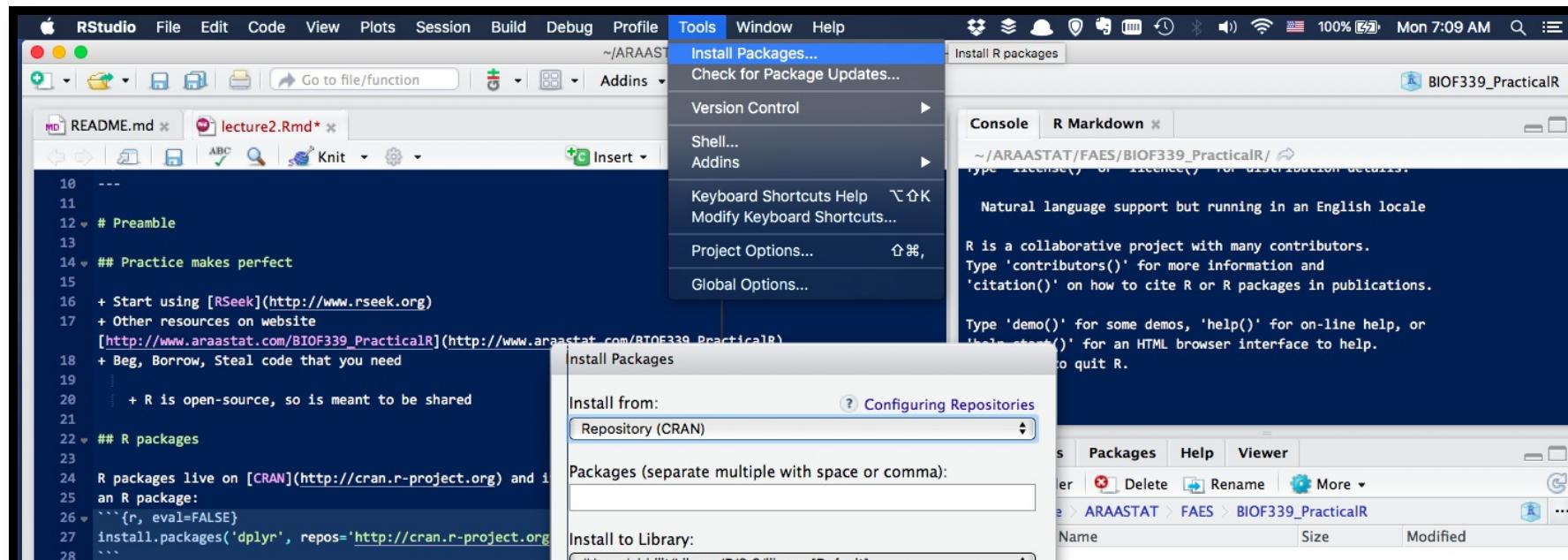
R packages

R packages live on **CRAN** and its mirrors. To install an R package:

```
install.packages('dplyr', repos='http://cran.r-project.org')
```

or

```
knitr:::include_graphics('lecture2_img/install_package.png')
```



R Packages

To use a package, or rather, use the functions from the package, you have to load it into R

```
library(dplyr)
```

We'll talk about packages later in the semester.

We will concentrate now on what is known as **Base R**, that is, the functions that are available when R is installed

Loading data

We will usually load CSV files, since they are the easiest for R.
The typical suggestion if you have Excel data is to save the sheet as a CSV and then import it into R.

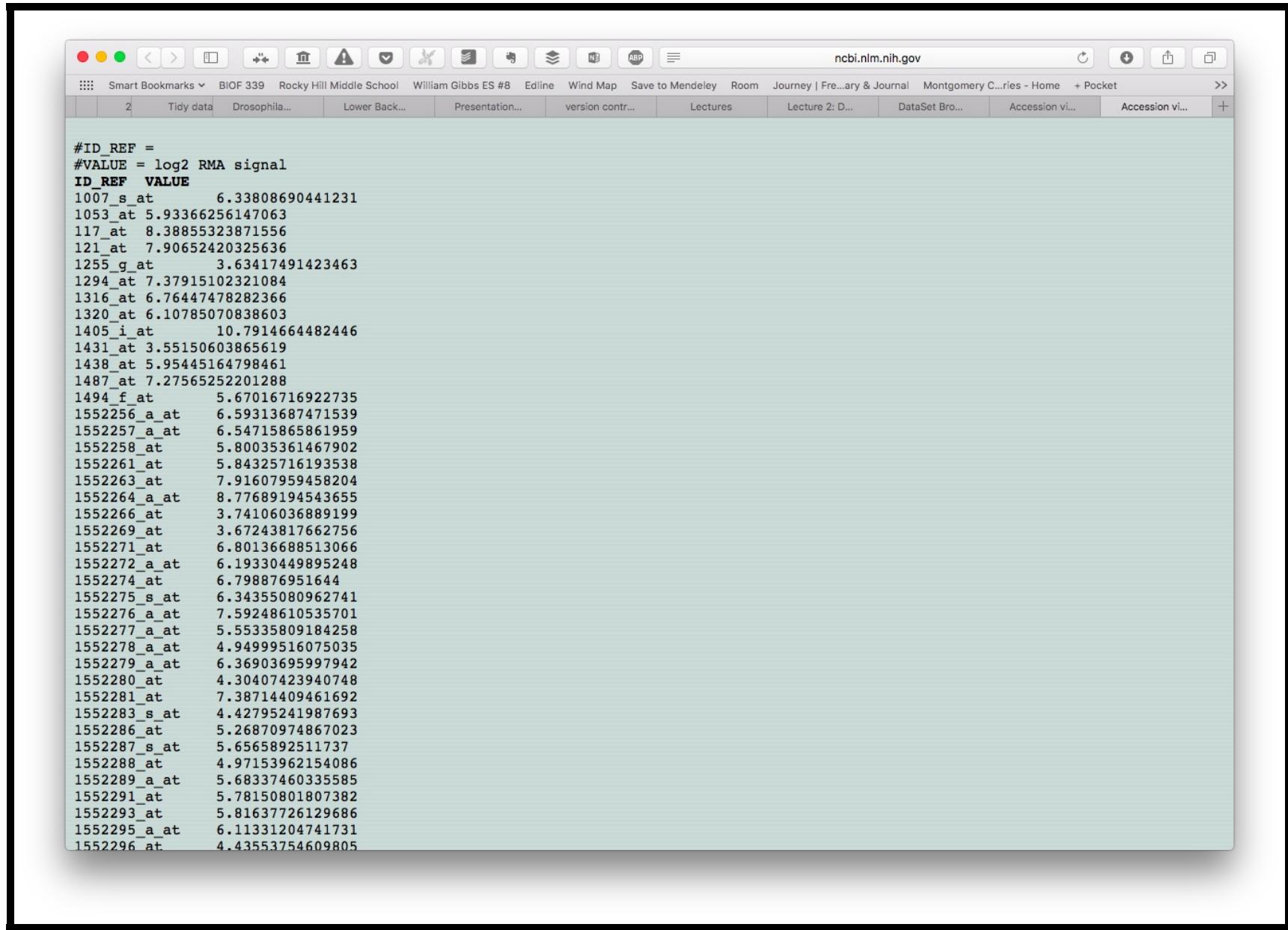
You can also load Excel files directly using either the `readxl` or `rio` packages

The structure of data sets

Tables

- Data is typically in a rectangular format
 - spreadsheet, database table
 - CSV (comma-separated values) or TSV (tab-separated values) files
- Characteristic
 - Rows are observations
 - Columns are variables
 - Each column has the same number of observations

*Tidy data is a particularly amenable format
for data analysis.*



The screenshot shows a web browser window with the URL ncbi.nlm.nih.gov in the address bar. The page content displays a list of gene expression values in a tabular format. The columns are labeled '#ID_REF' and 'VALUE'. The data consists of approximately 40 rows, each containing a gene identifier followed by its corresponding log2 RMA signal value.

#ID_REF	VALUE
1007_s_at	6.33808690441231
1053_at	5.93366256147063
117_at	8.38855323871556
121_at	7.90652420325636
1255_g_at	3.63417491423463
1294_at	7.37915102321084
1316_at	6.76447478282366
1320_at	6.10785070838603
1405_i_at	10.7914664482446
1431_at	3.55150603865619
1438_at	5.95445164798461
1487_at	7.27565252201288
1494_f_at	5.67016716922735
1552256_a_at	6.59313687471539
1552257_a_at	6.54715865861959
1552258_at	5.80035361467902
1552261_at	5.84325716193538
1552263_at	7.91607959458204
1552264_a_at	8.77689194543655
1552266_at	3.74106036889199
1552269_at	3.67243817662756
1552271_at	6.80136688513066
1552272_a_at	6.19330449895248
1552274_at	6.798876951644
1552275_s_at	6.34355080962741
1552276_a_at	7.59248610535701
1552277_a_at	5.55335809184258
1552278_a_at	4.94999516075035
1552279_a_at	6.36903695997942
1552280_at	4.30407423940748
1552281_at	7.38714409461692
1552283_s_at	4.42795241987693
1552286_at	5.26870974867023
1552287_s_at	5.6565892511737
1552288_at	4.97153962154086
1552289_a_at	5.68337460335585
1552291_at	5.78150801807382
1552293_at	5.81637726129686
1552295_a_at	6.11331204741731
1552296_at	4.43553754609805

An example [GEO](<http://www.ncbi.nlm.nih.gov/geo/>) dataset

Dataset_spine

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Pelvic incidence	Pelvic tilt	Lumbar lordosis angle	Sacral slope	Pelvic radius	Degree spondylolisthesis	Pelvic slope	Direct tilt	Thoracic slope	Cervical tilt	Sacrum angle	Scoliosis slope	Class attribute	
1	63.0278175	22.55258597	39.60911701	40.4752315	98.6729168	-0.254399986	0.74450346	12.5661	14.5386	15.30468	-28.658501	43.5123	Abnormal	
2	39.05695098	10.06099147	25.01537822	28.9959595	114.405425	4.564258645	0.41518568	12.8874	17.5323	16.78486	-25.530607	16.1102	Abnormal	
3	68.83202098	22.21848205	50.09219357	46.6135389	105.985136	-3.530317314	0.47488916	26.8343	17.4861	16.65897	-29.031888	19.2221	Abnormal	
4	69.29700807	24.65287791	44.31123813	44.6441302	101.868495	11.21152344	0.36934526	23.5603	12.7074	11.42447	-30.470246	18.8329	Abnormal	
5	49.71285934	9.652074879	28.317406	40.0607845	108.168725	7.918500615	0.54336047	35.494	15.9546	8.87237	-16.378376	24.9171	Abnormal	
6	40.25019968	13.92190658	25.1249496	26.3282931	130.327871	2.230651729	0.78999286	29.323	12.0036	10.40462	-1.512209	9.6548	Abnormal	
7	53.43292815	15.86433612	37.16593387	37.568592	120.567523	5.988550702	0.19891957	13.8514	10.7146	11.37832	-20.510434	25.9477	Abnormal	
8	45.36675362	10.75561143	29.03834896	34.6111422	117.270068	-10.67587083	0.13197256	28.8165	7.7676	7.60961	-25.111459	26.3543	Abnormal	
9	43.79019026	13.5337531	42.69081398	30.2564372	125.002893	13.28901817	0.19040763	22.7085	11.4234	10.59188	-20.020075	40.0276	Abnormal	
10	36.68635286	5.010884121	41.9487509	31.6754687	84.2414152	0.664437117	0.36770014	26.2011	8.738	14.91416	-1.702097	21.432	Abnormal	
11	49.70660953	13.04097405	31.33450009	36.6656355	108.648265	-7.825985755	0.6880095	31.3502	16.5097	15.17645	-0.502127	18.3437	Abnormal	
12	31.23238734	17.71581923	15.5	13.5165681	120.055399	0.499751446	0.60834276	21.4356	9.2589	14.76412	-21.724559	36.4449	Abnormal	
13	48.91555137	19.96455616	40.26379358	28.9509952	119.321358	8.028894629	0.13947817	32.7916	7.2049	8.61882	-1.215542	27.3713	Abnormal	
14	53.5721702	20.46082824	33.1	33.111342	110.966698	7.044802938	0.08193099	15.058	12.8127	12.00109	-1.734117	15.6205	Abnormal	
15	57.30022656	24.1888846	46.99999999	33.111342	116.806587	5.766946943	0.41672151	16.5158	18.6222	8.51898	-33.441303	13.2498	Abnormal	
16	44.31890674	12.53799164	36.098763	31.7809151	124.115836	5.415825143	0.66404088	9.5021	19.1756	7.25707	-32.893911	19.5695	Abnormal	
17	63.83498162	20.36250706	54.55243367	43.4724746	112.309492	-0.622526643	0.56067537	10.769	16.8116	11.41344	2.676002	17.3859	Abnormal	
18	31.27601184	3.14466948	32.56299592	28.1313424	129.011418	3.623020073	0.53448124	31.1641	18.6089	8.4402	4.482424	24.6513	Abnormal	
19	38.69791243	13.44474904	31	25.2531634	123.159251	1.429185758	0.30658054	28.3015	17.9575	14.75417	-14.252676	24.9361	Abnormal	
20	41.72996308	12.25407408	30.12258646	29.475889	116.585706	-1.244402488	0.46852593	28.5598	12.4637	14.1961	-20.392538	33.0265	Abnormal	
21	43.92283983	14.17795853	37.8325467	29.7448813	134.461016	6.451647637	0.28044621	12.4719	16.8965	10.32658	-4.986668	22.4667	Abnormal	
22	54.91944259	21.06233245	42.19999999	33.8571101	125.212716	2.432561437	0.17524457	23.0791	14.2195	14.14196	3.780394	24.9278	Abnormal	
23	63.07361096	24.41380271	53.99999999	38.6598083	106.42433	15.77969683	0.66638801	11.9696	17.6891	7.63771	-14.183602	44.2338	Abnormal	
24	45.54078988	13.06959759	30.29832059	32.4711923	117.98083	-4.987129618	0.56745008	23.8889	9.1019	7.70987	-19.37903	20.3649	Abnormal	
25	36.12568347	22.75875277	29	13.3669307	115.577116	-3.237562489	0.12647371	25.6206	15.7438	11.5561	-18.108941	24.1151	Abnormal	
26	54.12492019	26.65048856	35.32974693	27.4744316	121.447011	1.571204816	0.92868787	14.6686	13.57	16.12951	-17.630363	28.1902	Abnormal	
27	26.14792141	10.75945357	14	15.3884678	125.203296	-10.09310817	0.39197114	9.871	8.6406	15.78046	-19.650163	43.955	Abnormal	
28	43.58096394	16.5088837	46.99999999	27.0720802	109.271634	8.992815727	0.59417569	30.4577	17.97	10.79356	-25.180777	18.3196	Abnormal	
29	44.5510115	21.93114655	26.78591597	22.619865	111.07292	2.652320636	0.52789144	32.4275	10.2244	11.71324	-28.506125	28.047	Abnormal	
30	66.87921138	24.89199889	49.27859673	41.9872125	113.477018	-2.005891748	0.6772678	12.4271	8.2495	7.58784	-3.963385	27.3587	Abnormal	
31	50.81926781	15.40221253	42.52893886	35.4170553	112.192804	10.86956554	0.67898709	7.1103	7.2481	9.94785	-17.379206	14.7187	Abnormal	
32	46.39026008	11.07904664	32.13655345	35.3112134	98.7745463	6.386831648	0.06487251	14.2826	7.4515	7.30184	-24.360827	28.2366	Abnormal	
33	44.93667457	17.44383762	27.7805755	27.492837	117.980325	5.569619587	0.81674803	27.5218	13.8357	13.54721	-2.925586	36.0452	Abnormal	
34	38.66325708	12.98644139	39.99999999	25.6768157	124.914118	2.703008052	0.81594148	8.2045	7.5284	9.28229	-2.817753	31.5193	Abnormal	
35	59.59554032	31.99824445	46.56025198	27.5972959	119.330354	1.474285836	0.47708798	8.6051	8.3058	8.537	-0.029028	40.5823	Abnormal	
36	31.48421834	7.82622134	24.28481815	23.657997	113.833145	4.393080498	0.71315341	9.7107	8.1003	11.85555	-26.650369	12.6599	Abnormal	
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Lower back pain symptoms dataset on Kaggle.com

Excel File Edit View Insert Format Tools Data Window Help

clinical_data_breast_cancer

Search Sheet

Home Insert Page Layout Formulas Data Review View

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Complete TCGA ID	Gender	Age at Initial	ER Status	PR Status	HER2 Final Status	Tumor	Tumor--T1 Coded	Node	Node-Coded	Metastasis	Metastasis-C	AJCC Stage
2	TCGA-A2-A0T2	FEMALE	66	Negative	Negative	Negative	T3	T_Other	N3	Positive	M1	Positive	Stage IV
3	TCGA-A2-A0CM	FEMALE	40	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
4	TCGA-BH-A18V	FEMALE	48	Negative	Negative	Negative	T2	T_Other	N1	Positive	M0	Negative	Stage IIB
5	TCGA-BH-A18Q	FEMALE	56	Negative	Negative	Negative	T2	T_Other	N1	Positive	M0	Negative	Stage IIB
6	TCGA-BH-A0EO	FEMALE	38	Negative	Negative	Negative	T3	T_Other	N3	Positive	M0	Negative	Stage IIIC
7	TCGA-A7-A0CE	FEMALE	57	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
8	TCGA-D8-A142	FEMALE	74	Negative	Negative	Negative	T3	T_Other	N0	Negative	M0	Negative	Stage IIB
9	TCGA-A2-A0D0	FEMALE	60	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
10	TCGA-AO-A0J6	FEMALE	61	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
11	TCGA-A2-A0YM	FEMALE	67	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
12	TCGA-A2-A0D2	FEMALE	45	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIB
13	TCGA-A2-A0SX	FEMALE	48	Negative	Negative	Negative	T1	T1	N0	Negative	M0	Negative	Stage IA
14	TCGA-AO-A0JL	FEMALE	59	Negative	Negative	Negative	T2	T_Other	N2	Positive	M0	Negative	Stage IIIA
15	TCGA-AO-A12F	FEMALE	36	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
16	TCGA-AN-A0AL	FEMALE	41	Negative	Negative	Negative	T4	T_Other	N0	Negative	M0	Negative	Stage IIIB
17	TCGA-AN-A0FL	FEMALE	62	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
18	TCGA-AR-A0U4	FEMALE	54	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage II
19	TCGA-AR-A1AQ	FEMALE	49	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage II
20	TCGA-BH-A0AV	FEMALE	52	Negative	Negative	Negative	T1	T1	N0	Negative	M0	Negative	Stage I
21	TCGA-C8-A12V	FEMALE	55	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
22	TCGA-C8-A131	FEMALE	82	Negative	Negative	Negative	T2	T_Other	N2	Positive	M0	Negative	Stage III
23	TCGA-C8-A134	FEMALE	52	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
24	TCGA-E2-A150	FEMALE	48	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
25	TCGA-E2-A158	FEMALE	43	Negative	Negative	Negative	T1	T1	N1	Positive	M0	Negative	Stage IIA
26	TCGA-E2-A159	FEMALE	50	Negative	Negative	Negative	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
27	TCGA-BH-A18R	FEMALE	50	Indeterminat	Negative	Positive	T2	T_Other	N1	Positive	M0	Negative	Stage IB
28	TCGA-A2-A0T1	FEMALE	55	Negative	Negative	Positive	T3	T_Other	N3	Positive	M0	Negative	Stage IIIC
29	TCGA-BH-A0EE	FEMALE	68	Negative	Negative	Positive	T3	T_Other	N0	Negative	M0	Negative	Stage IIB
30	TCGA-A2-A0D1	FEMALE	76	Negative	Negative	Positive	T2	T_Other	N0	Negative	M0	Negative	Stage IIA
31	TCGA-AO-A12D	FEMALE	43	Negative	Negative	Positive	T1	T1	N1	Positive	M0	Negative	Stage IIA

clinical_data_breast_cancer +

Ready 150%

Breast Cancer Proteome dataset on Kaggle.com

Let's look at a dataset

The screenshot shows a Microsoft Excel spreadsheet titled "Dataset_spine". The window title bar includes the file name and the current date and time (Mon 9:37 AM). The ribbon menu is visible at the top, and the status bar at the bottom displays statistics: Average: 31.29389662, Count: 4043, Sum: 116413.2954. The main content area contains 4043 rows of data, each with 14 columns labeled A through M. Column M is labeled "Class attribute" and contains the classification "Abnormal" for most rows. The data includes various numerical values such as Pelvic incidence, Lumbar lordosis angle, Sacral slope, and others, along with their corresponding class labels.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Pelvic incidence	Pelvic tilt	Lumbar lordosis angle	Sacral slope	Pelvic radius	Degree spondylolisthesis	Pelvic slope	Direct tilt	Thoracic slope	Cervical tilt	Sacrum angle	Scoliosis slope	Class attribute	
2	63.0278175	22.55258597	39.60911701	40.4752315	98.6729168	-0.254399986	0.74450346	12.5661	14.5386	15.30468	-28.658501	43.5123	Abnormal	
3	39.05695098	10.06099147	25.01537822	28.9959595	114.405425	4.564258645	0.41518568	12.8874	17.5323	16.78486	-25.530607	16.1102	Abnormal	
4	68.83202098	22.21848205	50.09219357	46.6135389	105.985136	-3.530317314	0.47488916	26.8343	17.4861	16.65897	-29.031888	19.2221	Abnormal	
5	69.29700807	24.65287791	44.31123813	44.6441302	101.868495	11.21152344	0.36934526	23.5603	12.7074	11.42447	-30.470246	18.8329	Abnormal	
6	49.71285934	9.652074879	28.317406	40.0607845	108.168725	7.918500615	0.54336047	35.494	15.9546	8.87237	-16.378376	24.9171	Abnormal	
7	40.25019968	13.92190658	25.1249496	26.3282931	130.327871	2.230651729	0.78999286	29.323	12.0036	10.40462	-1.512209	9.5648	Abnormal	
8	53.43292815	15.86433612	37.16593387	37.568592	120.567523	5.988550702	0.19891957	13.8514	10.7146	11.37832	-20.510434	25.9477	Abnormal	
9	45.36675362	10.75561143	29.03834896	34.6111422	117.270068	-10.67587083	0.13197256	28.8165	7.7676	7.60961	-25.111459	26.3543	Abnormal	
10	43.79019026	13.5337531	42.69081398	30.2564372	125.002893	13.28901817	0.19040763	22.7085	11.4234	10.59188	-20.020075	40.0276	Abnormal	
11	36.68635286	5.010884121	41.9487509	31.6754687	84.2414152	0.664437117	0.36770014	26.2011	8.738	14.91416	-1.702097	21.432	Abnormal	
12	49.70660953	13.04097405	31.33450009	36.6656355	108.648265	-7.825985755	0.6880095	31.3502	16.5097	15.17645	-0.502127	18.3437	Abnormal	
13	31.23238734	17.71581923	15.5	13.5165681	120.055399	0.499751446	0.60834276	21.4356	9.2589	14.76412	-21.724559	36.4449	Abnormal	
14	48.91555137	19.96455616	40.26379358	28.950952	119.321358	8.028894629	0.13947817	32.7916	7.2049	8.61882	-1.215542	27.3713	Abnormal	
15	53.5721702	20.46082824	33.1	33.111342	110.966698	7.044802938	0.08193099	15.058	12.8127	12.00109	-1.734117	15.6205	Abnormal	
16	57.30022656	24.1888846	46.99999999	33.111342	116.806587	5.765946943	0.41672151	16.5158	18.6222	8.51198	-33.441303	13.2498	Abnormal	
17	44.31890674	12.53799164	36.098763	31.7809151	124.115836	5.415825143	0.66404088	9.5021	19.1756	7.25707	-32.893911	19.5695	Abnormal	
18	63.83498162	20.36250706	54.55243367	43.4724746	112.309492	-0.622526643	0.56067537	10.769	16.8116	11.41344	2.676002	17.3859	Abnormal	
19	31.27601184	3.14466948	32.56299592	28.1313424	129.011418	3.623020073	0.53448124	31.1641	18.6089	8.4402	4.482424	24.6513	Abnormal	
20	38.69791243	13.44474904	31	25.2531634	123.159251	1.429185758	0.30658054	28.3015	17.9575	14.75417	-14.252676	24.9361	Abnormal	
21	41.72996308	12.25407408	30.12258646	29.475889	116.585706	-1.244402488	0.46852593	28.5598	12.4637	14.1961	-20.392538	33.0265	Abnormal	
22	43.92283983	14.17795853	37.8325467	29.7448813	134.461016	6.451647637	0.28044621	12.4719	16.8965	10.32658	-4.986668	22.4667	Abnormal	
23	54.91944259	21.06233245	42.19999999	33.8571101	125.212716	2.432561437	0.17524457	23.0791	14.2195	14.14196	3.780394	24.9278	Abnormal	
24	63.07361096	24.41380271	53.99999999	38.6598083	106.42433	15.77969683	0.66638801	11.9696	17.6891	7.63771	-14.183602	44.2338	Abnormal	
25	45.54078988	13.06959759	30.29832059	32.4711923	117.98083	-4.987129618	0.56745008	23.8889	9.1019	7.70987	-19.37903	20.3649	Abnormal	
26	36.12568347	22.75875277	29	13.3669307	115.577116	-3.237562489	0.12647371	25.6206	15.7438	11.5561	-18.108941	24.1151	Abnormal	
27	54.12492019	26.65048856	35.32974693	27.4744316	121.447011	1.571204816	0.92868787	14.6686	13.57	16.12951	-17.630363	28.1902	Abnormal	
28	26.14792141	10.75945357	14	15.3884678	125.203296	-10.09310817	0.39197114	9.871	8.6406	15.78046	-19.650163	43.955	Abnormal	
29	43.58096394	16.5088837	46.99999999	27.0720802	109.271634	8.992815727	0.59417569	30.4577	17.97	10.79356	-25.180777	18.3196	Abnormal	
30	44.5510115	21.93114655	26.78591597	22.619865	111.07292	2.652320636	0.52789144	32.4275	10.2244	11.71324	-28.506125	28.047	Abnormal	
31	66.87921138	24.89199889	49.27859673	41.9872125	113.477018	-2.005891748	0.6772678	12.4271	8.2495	7.58784	-3.963385	27.3587	Abnormal	
32	50.81926781	15.40221253	42.52893886	35.4170553	112.192804	10.86956554	0.67898709	7.1103	7.2481	9.94785	-17.379206	14.7187	Abnormal	
33	46.39026008	11.07904664	32.13655345	35.3112134	98.7745463	6.386831648	0.06487251	14.2826	7.4515	7.30184	-24.360827	28.2366	Abnormal	
34	44.93667457	17.44383762	27.78057555	27.492837	117.980325	5.569619587	0.81674803	27.5218	13.8357	13.54721	-2.925586	36.0452	Abnormal	
35	38.66325708	12.98644139	39.99999999	25.6768157	124.914118	2.703008052	0.81594148	30.2045	7.5284	9.28229	-2.817753	31.5193	Abnormal	
36	59.59554032	31.99824445	46.56025198	27.5972959	119.330354	1.474285836	0.47708798	8.6051	8.3058	8.537	-0.029028	40.5823	Abnormal	
37	31.48421834	7.82622134	24.28481815	23.657997	113.833145	4.393080498	0.71315341	9.7107	8.1003	11.85555	-26.650369	12.6599	Abnormal	
38	33.82121834	10.82622134	24.28481815	23.657997	113.833145	4.393080498	0.71315341	9.7107	8.1003	11.85555	-26.650369	12.659		

Let's look at a dataset

```
data_spine <- read.csv('lecture2_data/Dataset_spine.csv')
```

```
head(data_spine)
```

```
##   Pelvic.incidence Pelvic.tilt Lumbar.lordosis.angle Sacral.slope
## 1      63.02782     22.552586          39.60912      40.47523
## 2      39.05695     10.060991          25.01538      28.99596
## 3      68.83202     22.218482          50.09219      46.61354
## 4      69.29701     24.652878          44.31124      44.64413
## 5      49.71286     9.652075          28.31741      40.06078
## 6      40.25020     13.921907          25.12495      26.32829
##   Pelvic.radius Degree.spondylolisthesis Pelvic.slope Direct.tilt
## 1      98.67292           -0.254400      0.7445035     12.5661
## 2     114.40543            4.564259      0.4151857     12.8874
## 3     105.98514           -3.530317      0.4748892     26.8343
## 4     101.86850            11.211523      0.3693453     23.5603
## 5     108.16872            7.918501      0.5433605     35.4940
## 6     130.32787            2.230652      0.7899929     29.3230
##   Thoracic.slope Cervical.tilt Sacrum.angle Scoliosis.slope
## 1      14.5386       15.30468      -28.658501      43.5123
## 2      17.5323       16.78486      -25.530607      16.1102
## 3      17.4861       16.65897      -29.031888      19.2221
```

Ignore the first ##; it denotes that this is R output

Let's look at a dataset

- Assumes that the first row has variable names
- Replaces spaces with .
- Keeps numeric and character variables together

Let's look at a dataset

```
View(data_spine) ## It looks like a matrix
```

```
knitr::include_graphics('lecture2_img/View.png')
```

	Pelvic.incidence	Pelvic.tilt	Lumbar.lordosis.angle	Sacral.slope	Pelvic.radius	Degree.spondylolisthesis	Pelvic.slope	Direct.tilt	Thoracic.slope	Cervical.tilt	Sacrum.angle	Scoliosis.slope	Class.attribute
1	63.02782	22.5525860	39.60912	40.47523	98.67292	-0.2544000	0.744503464	12.5661	14.5386	15.30468	-28.658501	43.5123	Abnormal
2	39.05695	10.0609915	25.01538	28.99596	114.40543	4.5642586	0.415185678	12.8874	17.5323	16.78486	-25.530607	16.1102	Abnormal
3	68.83202	22.2184820	50.09219	46.61354	105.98514	-3.5303173	0.474889164	26.8343	17.4861	16.65897	-29.031888	19.2221	Abnormal
4	69.29701	24.6528779	44.31124	44.64413	101.86850	11.2115234	0.369345264	23.5603	12.7074	11.42447	-30.470246	18.8329	Abnormal
5	49.71286	9.6520749	28.31741	40.06078	108.16872	7.9185006	0.543360472	35.4940	15.9546	8.87237	-16.378376	24.9171	Abnormal
6	40.25020	13.9219066	25.12495	26.32829	130.32787	2.2306517	0.789992856	29.3230	12.0036	10.40462	-1.512209	9.6548	Abnormal
7	53.43293	15.8643361	37.16593	37.56859	120.56752	5.9885507	0.198919573	13.8514	10.7146	11.37832	-20.510434	25.9477	Abnormal
8	45.36675	10.7556114	29.03835	34.61114	117.27007	-10.6758708	0.131972555	28.8165	7.7676	7.60961	-25.111459	26.3543	Abnormal
9	43.79019	13.5337531	42.69081	30.25644	125.00289	13.2890182	0.190407626	22.7085	11.4234	10.59188	-20.020075	40.0276	Abnormal
10	36.68635	5.0108841	41.94875	31.67547	84.24142	0.6644371	0.367700139	26.2011	8.7380	14.91416	-1.702097	21.4320	Abnormal
11	49.70661	13.0409741	31.33450	36.66564	108.64827	-7.8259858	0.688009500	31.3502	16.5097	15.17645	-0.502127	18.3437	Abnormal
12	31.23239	17.7158192	15.50000	13.51657	120.05540	0.4997514	0.608342758	21.4356	9.2589	14.76412	-21.724559	36.4449	Abnormal
13	48.91555	19.9645562	40.26379	28.95100	119.32136	8.0288946	0.139478165	32.7916	7.2049	8.61882	-1.215542	27.3713	Abnormal
14	53.57217	20.4608282	33.10000	33.11134	110.96670	7.0448029	0.081930993	15.0580	12.8127	12.00109	-1.734117	15.6205	Abnormal
15	57.30023	24.1888846	47.00000	33.11134	116.80659	5.7669469	0.416721511	16.5158	18.6222	8.51898	-33.441303	13.2498	Abnormal
16	44.31891	12.5379916	36.09876	31.78092	124.11584	5.4158251	0.664040876	9.5021	19.1756	7.25707	-32.893911	19.5695	Abnormal
17	63.83498	20.3625071	54.55243	43.47247	112.30949	-0.6225266	0.560675371	10.7690	16.8116	11.41344	2.676002	17.3859	Abnormal
18	31.27601	3.1446695	32.56300	28.13134	129.01142	3.6230201	0.534481238	31.1641	18.6089	8.44020	4.482424	24.6513	Abnormal
19	38.69791	13.4447490	31.00000	25.25316	123.15925	1.4291858	0.306580540	28.3015	17.9575	14.75417	-14.252676	24.9361	Abnormal
20	41.72996	12.2540741	30.12259	29.47589	116.58571	-1.2444025	0.468525928	28.5598	12.4637	14.19610	-20.392538	33.0265	Abnormal
21	43.92284	14.1779585	37.83255	29.74488	134.46102	6.4516476	0.280446206	12.4719	16.8965	10.32658	-4.986668	22.4667	Abnormal
22	54.91944	21.0623324	42.20000	33.85711	125.21272	2.4325614	0.175244572	23.0791	14.2195	14.14196	3.780394	24.9278	Abnormal
23	63.07361	24.4138027	54.00000	38.65981	106.42433	15.7796968	0.666388008	11.9696	17.6891	7.63771	-14.183602	44.2338	Abnormal
24	45.54079	13.0695976	30.29832	32.47119	117.98083	-4.9871296	0.567450078	23.8889	9.1019	7.70987	-19.379030	20.3649	Abnormal
25	36.12568	22.7587528	29.00000	13.36693	115.57712	-3.2375625	0.126473707	25.6206	15.7438	11.55610	-18.108941	24.1151	Abnormal
26	54.12492	26.6504886	35.32975	27.47443	121.44701	1.5712048	0.928687869	14.6686	13.5700	16.12951	-17.630363	28.1902	Abnormal
27	26.14792	10.7594536	14.00000	15.38847	125.20330	-10.0931082	0.391971136	9.8710	8.6406	15.78046	-19.650163	43.9550	Abnormal
28	43.58096	16.5088837	47.00000	27.07208	109.27163	8.9928157	0.594175694	30.4577	17.9700	10.79356	-25.180777	18.3196	Abnormal
29	44.55101	21.9311466	26.78592	22.61986	111.07292	2.6523206	0.527891438	32.4275	10.2244	11.71324	-28.506125	28.0470	Abnormal
30	66.87921	24.8919989	49.27860	41.98721	113.47702	-2.0058917	0.677267795	12.4271	8.2495	7.58784	-3.963385	27.3587	Abnormal
31	50.81927	15.4022125	42.52894	35.41706	112.19280	10.8695655	0.678987086	7.1103	7.2481	9.94785	-17.379206	14.7187	Abnormal

Let's look at a dataset

```
str(data_spine) ## Structure of a dataset
```

```
## 'data.frame': 310 obs. of 13 variables:  
## $ Pelvic.incidence : num 63 39.1 68.8 69.3 49.7 ...  
## $ Pelvic.tilt : num 22.55 10.06 22.22 24.65 9.65 ...  
## $ Lumbar.lordosis.angle : num 39.6 25 50.1 44.3 28.3 ...  
## $ Sacral.slope : num 40.5 29 46.6 44.6 40.1 ...  
## $ Pelvic.radius : num 98.7 114.4 106 101.9 108.2 ...  
## $ Degree.spondylolisthesis: num -0.254 4.564 -3.53 11.212 7.919 ...  
## $ Pelvic.slope : num 0.745 0.415 0.475 0.369 0.543 ...  
## $ Direct.tilt : num 12.6 12.9 26.8 23.6 35.5 ...  
## $ Thoracic.slope : num 14.5 17.5 17.5 12.7 16 ...  
## $ Cervical.tilt : num 15.3 16.78 16.66 11.42 8.87 ...  
## $ Sacrum.angle : num -28.7 -25.5 -29 -30.5 -16.4 ...  
## $ Scoliosis.slope : num 43.5 16.1 19.2 18.8 24.9 ...  
## $ Class.attribute : Factor w/ 2 levels "Abnormal","Normal":
```

So this is a `data.frame` object with 310 observations and 13 variables, of which one is a **factor** and the rest are **numeric**

It looks like a **list of things**

Dataframes

Dataframes are the primary mode of storing datasets in R

They were revolutionary in that they kept heterogeneous data together

They share properties of both a **matrix** and a **list**

```
class(data_spine)
```

```
## [1] "data.frame"
```

Technically, a data.frame is a list of vectors (or objects, generally) of the same length

Matrices

A **matrix** is a rectangular array of data *of the same type*

```
matrix(0, nrow=2, ncol=4)
```

```
## [,1] [,2] [,3] [,4]
## [1,] 0 0 0 0
## [2,] 0 0 0 0
```

```
matrix(letters, nrow=2)
```

```
## [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [
## [1,] "a" "c" "e" "g" "i" "k" "m" "o" "q" "s" "u" "w"
## [2,] "b" "d" "f" "h" "j" "l" "n" "p" "r" "t" "v" "x"
```

```
matrix(letters, nrow=2, byrow=T)
```

```
## [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [
## [1,] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l"
## [2,] "n" "o" "p" "q" "r" "s" "t" "u" "v" "w" "x" "y"
```

Matrices

You can create a matrix from a set of *vectors* of the same length

```
x <- c(1,2,3,4)  
y <- c(10,20,30,40)
```

Put columns together

```
cbind(c(1,2,3,4), c(10,20,30,40)) ## Column bind
```

```
##      [,1] [,2]  
## [1,]    1   10  
## [2,]    2   20  
## [3,]    3   30  
## [4,]    4   40
```

Matrices

You can create a matrix from a set of *vectors* of the same length

```
x <- c(1,2,3,4)  
y <- c(10,20,30,40)
```

Put rows together

```
example_matrix <- rbind(c(1,2,3,4), c(10,20,30,40)) ## Row bind  
example_matrix
```

```
##      [,1] [,2] [,3] [,4]  
## [1,]    1    2    3    4  
## [2,]   10   20   30   40
```

Extracting elements

```
example_matrix
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]   10   20   30   40
```

```
example_matrix[1,] ## Extracts 1st row
```

```
## [1] 1 2 3 4
```

```
example_matrix[,2:3] ## extracts 2nd & 3rd columns
```

```
##      [,1] [,2]
## [1,]    2    3
## [2,]   20   30
```

```
example_matrix[1,4]
```

Matrix properties

```
example_matrix
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]   10   20   30   40
```

```
nrow(example_matrix) ## Number of rows
```

```
## [1] 2
```

```
ncol(example_matrix) ## Number of columns
```

```
## [1] 4
```

```
dim(example_matrix) ## shortcut for above
```

```
## [1] 2 4
```

Matrix arithmetic

```
example_matrix
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]   10   20   30   40
```

```
example_matrix + 5 ## Add 5 to each element
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    6    7    8    9
## [2,]   15   25   35   45
```

```
example_matrix * 2 ## Multiply each element by 2
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    2    4    6    8
## [2,]   20   40   60   80
```

Two matrices

```
example_matrix
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]   10   20   30   40
```

```
example_matrix2 <- rbind(3:6, 9:12)
example_matrix2
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    3    4    5    6
## [2,]    9   10   11   12
```

```
example_matrix + example_matrix2
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    4    6    8   10
## [2,]   19   30   41   52
```

Two matrices

```
example_matrix
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]   10   20   30   40
```

```
example_matrix2
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    3    4    5    6
## [2,]    9   10   11   12
```

```
example_matrix * example_matrix2 ## Not matrix multiplication, but element-wise multiplication
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    3    8   15   24
## [2,]   90   200  330  480
```

Two matrices

```
rbind(example_matrix, example_matrix2)
```

```
##      [,1] [,2] [,3] [,4]
## [1,]     1    2    3    4
## [2,]    10   20   30   40
## [3,]     3    4    5    6
## [4,]     9   10   11   12
```

```
cbind(example_matrix, example_matrix2)
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
## [1,]     1    2    3    4    3    4    5    6
## [2,]    10   20   30   40   9   10   11   12
```

Two matrices

```
dim(example_matrix2)
```

```
## [1] 2 4
```

```
t(example_matrix2) ## Transpose of a matrix
```

```
## [,1] [,2]
## [1,]    3    9
## [2,]    4   10
## [3,]    5   11
## [4,]    6   12
```

```
example_matrix %*% t(example_matrix2) ## Matrix multiplication
```

```
## [,1] [,2]
## [1,]   50   110
## [2,]  500  1100
```

Lists

Lists are collections of arbitrary objects in R

```
example_list <- list(c('Andy', 'Brian', 'Harry'),  
                      c(12, 16, 16),  
                      c(TRUE, TRUE, FALSE),  
                      matrix(1, nrow=2, ncol=3))  
example_list
```

```
## [[1]]  
## [1] "Andy"  "Brian" "Harry"  
##  
## [[2]]  
## [1] 12 16 16  
##  
## [[3]]  
## [1] TRUE  TRUE FALSE  
##  
## [[4]]  
##      [,1] [,2] [,3]  
## [1,]    1    1    1  
## [2,]    1    1    1
```

Extracting elements from lists

```
example_list[[3]]
```

```
## [1] TRUE TRUE FALSE
```

```
example_list[1:2]
```

```
## [[1]]
## [1] "Andy"  "Brian" "Harry"
##
## [[2]]
## [1] 12 16 16
```

Extracting elements from lists

```
example_list[[4]]
```

```
##      [,1] [,2] [,3]
## [1,]    1    1    1
## [2,]    1    1    1
```

```
class(example_list[[4]])
```

```
## [1] "matrix"
```

```
example_list[[4]][1,]
```

```
## [1] 1 1 1
```

Named lists

```
example_named_list <- list('Names' = c('Andy', 'Brian', 'Harry'),  
                           "YearsOfEducation" = c(12, 16, 16),  
                           "Married" = c(TRUE, TRUE, FALSE),  
                           'something' = matrix(1, nrow=2, ncol=3))  
  
example_named_list[['Names']]
```

```
## [1] "Andy"  "Brian" "Harry"
```

```
example_named_list$Names
```

```
## [1] "Andy"  "Brian" "Harry"
```

```
example_named_list$Names[3]
```

```
## [1] "Harry"
```

Back to a Data Frame

A `data.frame` object is a **named list** where each element is of the same length

You can use both *matrix* and *list* functions to operate on `data.frame` objects!!

Data Frames

```
head(data_spine)
```

```
##   Pelvic.incidence Pelvic.tilt Lumbar.lordosis.angle Sacral.slope
## 1      63.02782    22.552586          39.60912     40.47523
## 2      39.05695    10.060991          25.01538     28.99596
## 3      68.83202    22.218482          50.09219     46.61354
## 4      69.29701    24.652878          44.31124     44.64413
## 5      49.71286    9.652075          28.31741     40.06078
## 6      40.25020   13.921907          25.12495     26.32829
##   Pelvic.radius Degree.spondylolisthesis Pelvic.slope Direct.tilt
## 1      98.67292           -0.254400      0.7445035    12.5661
## 2     114.40543            4.564259      0.4151857    12.8874
## 3     105.98514           -3.530317      0.4748892    26.8343
## 4     101.86850            11.211523     0.3693453    23.5603
## 5     108.16872            7.918501      0.5433605    35.4940
## 6     130.32787            2.230652      0.7899929    29.3230
##   Thoracic.slope Cervical.tilt Sacrum.angle Scoliosis.slope
## 1      14.5386       15.30468      -28.658501     43.5123
## 2      17.5323       16.78486      -25.530607     16.1102
## 3      17.4861       16.65897      -29.031888     19.2221
```

Data Frames

```
dim(data_spine)
```

```
## [1] 310 13
```

```
nrow(data_spine)
```

```
## [1] 310
```

```
data_spine_small <- data_spine[1:4,] ## Matrix operation
```

Data Frames

```
data_spine_small[,2] ## Matrix extraction by position
```

```
## [1] 22.55259 10.06099 22.21848 24.65288
```

```
data_spine_small[[2]] ## List extraction by position
```

```
## [1] 22.55259 10.06099 22.21848 24.65288
```

Data Frames

```
data_spine_small[['Pelvic.tilt']] ## Named list extraction
```

```
## [1] 22.55259 10.06099 22.21848 24.65288
```

```
data_spine_small[, 'Pelvic.tilt'] ## Data frame named column extraction
```

```
## [1] 22.55259 10.06099 22.21848 24.65288
```

```
data_spine_small$Pelvic.tilt ## Dollar sign extraction
```

```
## [1] 22.55259 10.06099 22.21848 24.65288
```

Data Frames

My preference is for

1. *data frame named column extraction*

```
data_spine_small[, 'Pelvic.tilt'],
```

2. *named list extraction*

```
data_spine_small[['Pelvic.tilt']]
```

3. *Dollar-based extraction*

```
data_spine_small$Pelvic.tilt
```

Data Frames

```
names(data_spine_small)
```

```
## [1] "Pelvic.incidence"          "Pelvic.tilt"  
## [3] "Lumbar.lordosis.angle"    "Sacral.slope"  
## [5] "Pelvic.radius"            "Degree.spondylolisthesis"  
## [7] "Pelvic.slope"              "Direct.tilt"  
## [9] "Thoracic.slope"            "Cervical.tilt"  
## [11] "Sacrum.angle"              "Scoliosis.slope"  
## [13] "Class.attribute"
```

```
data_spine_small[, c('Pelvic.tilt', 'Pelvic.slope', 'Class.attribute')]
```

```
##   Pelvic.tilt Pelvic.slope Class.attribute  
## 1    22.55259     0.7445035      Abnormal  
## 2    10.06099     0.4151857      Abnormal  
## 3    22.21848     0.4748892      Abnormal  
## 4    24.65288     0.3693453      Abnormal
```

Filtering data frames

Boolean operators

Operator	Meaning
	Or
&	And
!	Not

Filtering data frames

```
data_spine[data_spine$Pelvic.tilt > 20, ]
```

	Pelvic.incidence	Pelvic.tilt	Lumbar.lordosis.angle	Sacral.slope
## 1	63.02782	22.55259	39.60912	40.47523
## 3	68.83202	22.21848	50.09219	46.61354
## 4	69.29701	24.65288	44.31124	44.64413
## 14	53.57217	20.46083	33.10000	33.11134
## 15	57.30023	24.18888	47.00000	33.11134
## 17	63.83498	20.36251	54.55243	43.47247
## 22	54.91944	21.06233	42.20000	33.85711
## 23	63.07361	24.41380	54.00000	38.65981
## 25	36.12568	22.75875	29.00000	13.36693
## 26	54.12492	26.65049	35.32975	27.47443
## 29	44.55101	21.93115	26.78592	22.61986
## 30	66.87921	24.89200	49.27860	41.98721
## 35	59.59554	31.99824	46.56025	27.59730
## 39	55.84329	28.84745	47.69054	26.99584
## 44	66.28539	26.32784	47.50000	39.95755
## 46	50.91244	23.01517	47.00000	27.89727

```
subset(data_spine, Pelvic.tilt > 20) ## is equivalent
```

Filtering data frames

```
data_spine[data_spine$Pelvic.tilt > 20 & data_spine$Pelvic.slope > 0.85,
```

	Pelvic.incidence	Pelvic.tilt	Lumbar.lordosis.angle	Sacral.slope
##				
## 26	54.12492	26.65049	35.32975	27.47443
## 76	70.22145	39.82272	68.11840	30.39873
## 84	81.10410	24.79417	77.88702	56.30993
## 99	77.65512	22.43295	93.89278	55.22217
## 106	65.00796	27.60261	50.94752	37.40536
## 112	84.99896	29.61010	83.35219	55.38886
## 129	90.51396	28.27250	69.81394	62.24146
## 179	80.65432	26.34438	60.89812	54.30994
## 231	65.61180	23.13792	62.58218	42.47388
## 303	54.60032	21.48897	29.36022	33.11134
##	Pelvic.radius	Degree.spondylolisthesis	Pelvic.slope	Direct.tilt
## 26	121.4470	1.571205	0.9286879	14.6686
## 76	148.5256	145.378143	0.9466106	10.3840
## 84	151.8399	65.214616	0.9720056	10.5715
## 99	123.0557	61.211187	0.9249029	14.9502
## 106	116.5811	7.015978	0.8673241	12.1292

```
subset(data_spine, Pelvic.tilt > 20 & Pelvic.slope > 0.85)
```

Filtering data frames and selecting variables

```
data_spine[data_spine$Pelvic.tilt > 20 & data_spine$Pelvic.slope > 0.85,  
          c('Direct.tilt', 'Class.attribute')]
```

```
##      Direct.tilt Class.attribute  
## 26      14.6686    Abnormal  
## 76      10.3840    Abnormal  
## 84      10.5715    Abnormal  
## 99      14.9502    Abnormal  
## 106     12.1292    Abnormal  
## 112      7.0551    Abnormal  
## 129     13.5739    Abnormal  
## 179     20.0845    Abnormal  
## 231     30.0422    Normal  
## 303     30.8554    Normal
```

Adding a variable

```
data_spine_small[, 'bad.angle'] <- c('No', 'Yes', 'No', 'No')  
data_spine_small
```

```
##   Pelvic.incidence Pelvic.tilt Lumbar.lordosis.angle Sacral.slope  
## 1      63.02782     22.55259          39.60912    40.47523  
## 2      39.05695     10.06099          25.01538    28.99596  
## 3      68.83202     22.21848          50.09219    46.61354  
## 4      69.29701     24.65288          44.31124    44.64413  
##   Pelvic.radius Degree.spondylolisthesis Pelvic.slope Direct.tilt  
## 1      98.67292           -0.254400     0.7445035    12.5661  
## 2     114.40543            4.564259     0.4151857    12.8874  
## 3     105.98514           -3.530317     0.4748892    26.8343  
## 4     101.86850            11.211523    0.3693453    23.5603  
##   Thoracic.slope Cervical.tilt Sacrum.angle Scoliosis.slope  
## 1      14.5386       15.30468        -28.65850    43.5123  
## 2      17.5323       16.78486        -25.53061    16.1102  
## 3      17.4861       16.65897        -29.03189    19.2221  
## 4      12.7074       11.42447        -30.47025    18.8329  
##   Class.attribute bad.angle  
## 1      Abnormal        No  
## 2      Abnormal        Yes
```

```
data_spine_small$bad.angle <- ...  
data_spine_small[['bad.angle']] <- ...
```

Removing a variable

```
data_spine_small[, -c(13,14)]  
  
data_spine_small[,-c('Class.attribute', 'bad.angle')]  
  
## The next two commands change the original data set  
  
data_spine_small[c('Class.attribute','bad.angle')] <- NULL  
  
data_spine_small[['bad.angle']] <- NULL
```

Creating derived variables

```
data_spine_small$bad.angle <- ifelse(data_spine_small$Sacrum.angle > 80,  
                                      'Yes', 'No')
```

Creating derived variables

```
data_spine_small <- transform(data_spine_small,  
                                bad.angle = ifelse(Sacrum.angle > 80,  
                                         'Yes', 'No'))
```

For deriving multiple variables into a data frame

```
head(mtcars)
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
## Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
## Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
## Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
## Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
## Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2
## Valiant	18.1	6	225	105	2.76	3.460	20.22	1	0	3	1

For deriving multiple variables into a data frame

```
mtcars <- transform(mtcars,  
  kmpg = mpg * 1.6, ## Numerical vector  
  low.mpg = ifelse(mpg < 16, 'Yes', 'No') ## Factor  
)
```

For deriving multiple variables into a data frame

```
str(mtcars)
```

```
## 'data.frame': 32 obs. of 13 variables:  
## $ mpg : num 21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...  
## $ cyl : num 6 6 4 6 8 6 8 4 4 6 ...  
## $ disp : num 160 160 108 258 360 ...  
## $ hp : num 110 110 93 110 175 105 245 62 95 123 ...  
## $ drat : num 3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...  
## $ wt : num 2.62 2.88 2.32 3.21 3.44 ...  
## $ qsec : num 16.5 17 18.6 19.4 17 ...  
## $ vs : num 0 0 1 1 0 1 0 1 1 1 ...  
## $ am : num 1 1 1 0 0 0 0 0 0 0 ...  
## $ gear : num 4 4 4 3 3 3 3 4 4 4 ...  
## $ carb : num 4 4 1 1 2 1 4 2 2 4 ...  
## $ kmpg : num 33.6 33.6 36.5 34.2 29.9 ...  
## $ low.mpg: Factor w/ 2 levels "No", "Yes": 1 1 1 1 1 1 2 1 1 1 ...
```

Adding new data to a data frame

You can concatenate two data frames using `rbind` as long as the variable names and orders are the same

```
new_data = rbind(data_spine[1:4,], data_spine[c(8,22),])  
new_data
```

	Pelvic.incidence	Pelvic.tilt	Lumbar.lordosis.angle	Sacral.slope
## 1	63.02782	22.55259	39.60912	40.47523
## 2	39.05695	10.06099	25.01538	28.99596
## 3	68.83202	22.21848	50.09219	46.61354
## 4	69.29701	24.65288	44.31124	44.64413
## 8	45.36675	10.75561	29.03835	34.61114
## 22	54.91944	21.06233	42.20000	33.85711
	Pelvic.radius	Degree.spondylolisthesis	Pelvic.slope	Direct.tilt
## 1	98.67292	-0.254400	0.7445035	12.5661
## 2	114.40543	4.564259	0.4151857	12.8874
## 3	105.98514	-3.530317	0.4748892	26.8343
## 4	101.86850	11.211523	0.3693453	23.5603
## 8	117.27007	-10.675871	0.1319726	28.8165
## 22	125.21272	2.432561	0.1752446	23.0791
	Thoracic.slope	Cervical.tilt	Sacrum.angle	Scoliosis.slope
## 1	14.5386	15.30468	-28.658501	43.5123
## 2	17.5323	16.78486	-25.530607	16.1102
## 3	17.4861	16.65897	-29.021888	19.3331

Adding new data to a data frame

You can add columns of a new data frame to an existing data frame using `cbind` as long as the columns have no common names

```
new_data2 <- cbind(data_spine[1:4, c('Pelvic.slope', 'Class.attribute')],  
                     data.frame(Sex = c('M', 'F', 'M', 'M'), ## Creating c  
                     Race = c('W', 'B', 'As', 'B'))  
)  
new_data2
```

```
##   Pelvic.slope Class.attribute Sex Race  
## 1     0.7445035      Abnormal    M    W  
## 2     0.4151857      Abnormal    F    B  
## 3     0.4748892      Abnormal    M   As  
## 4     0.3693453      Abnormal    M    B
```