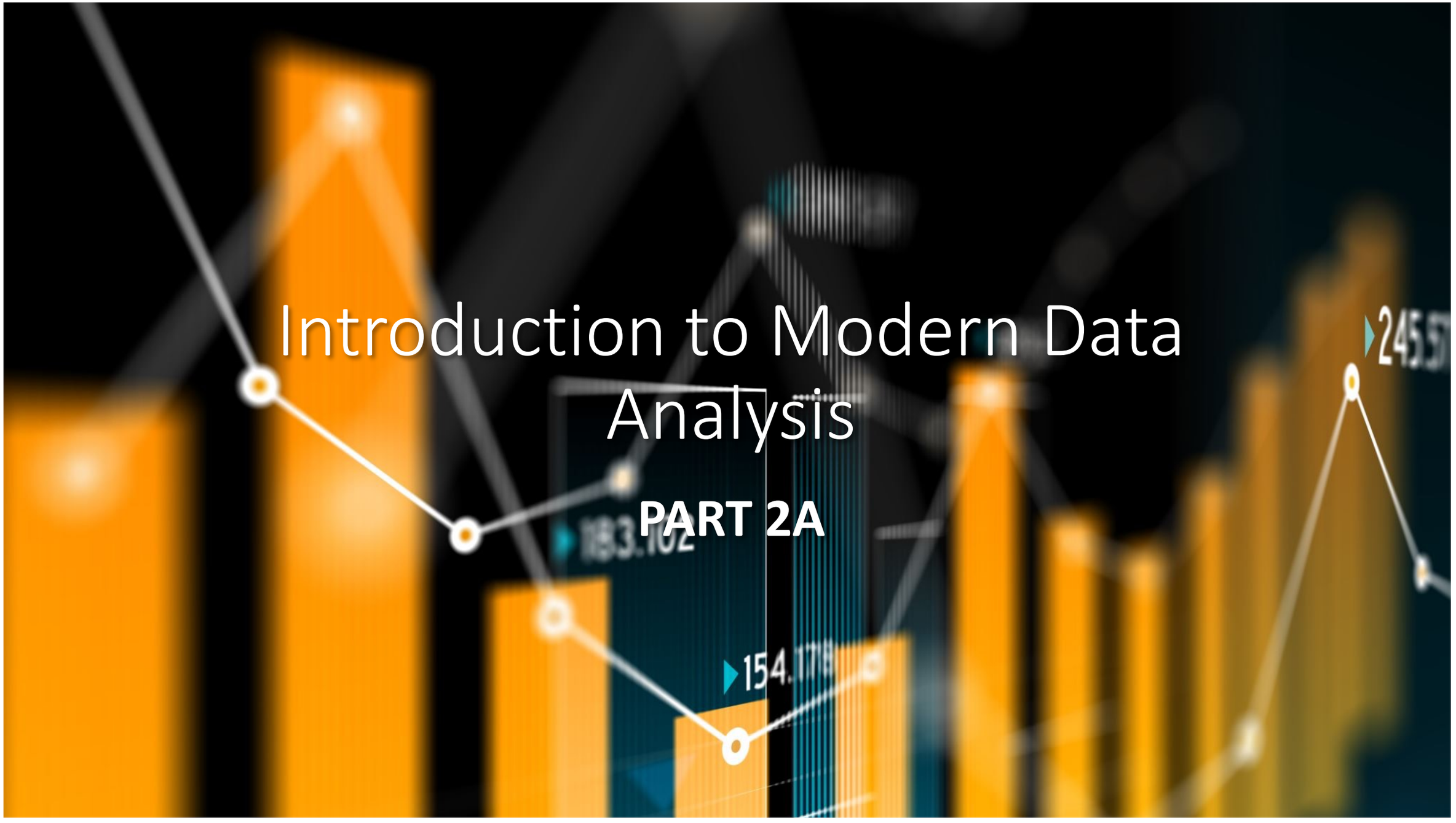
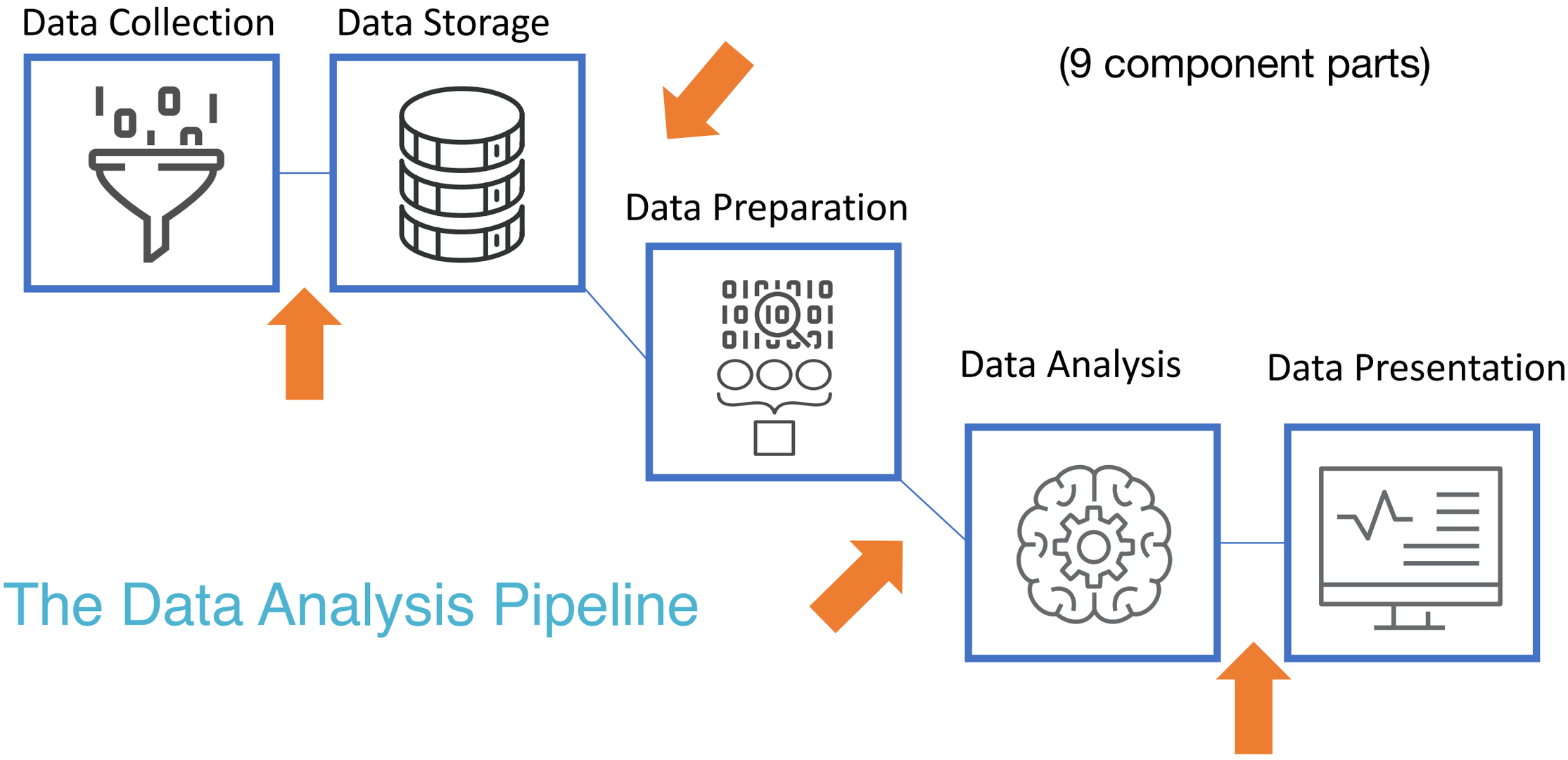
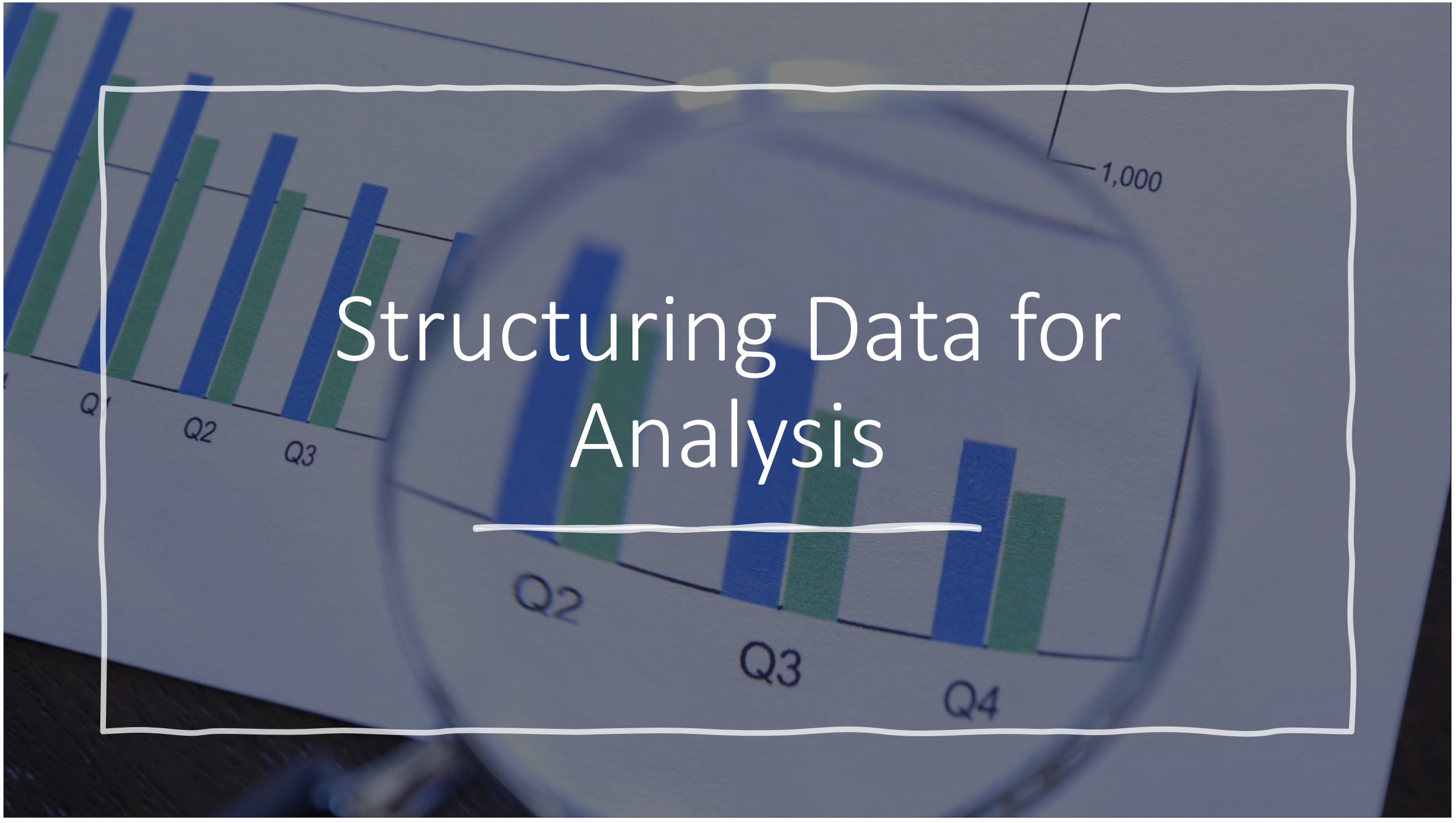


Introduction to Modern Data Analysis

PART 2A



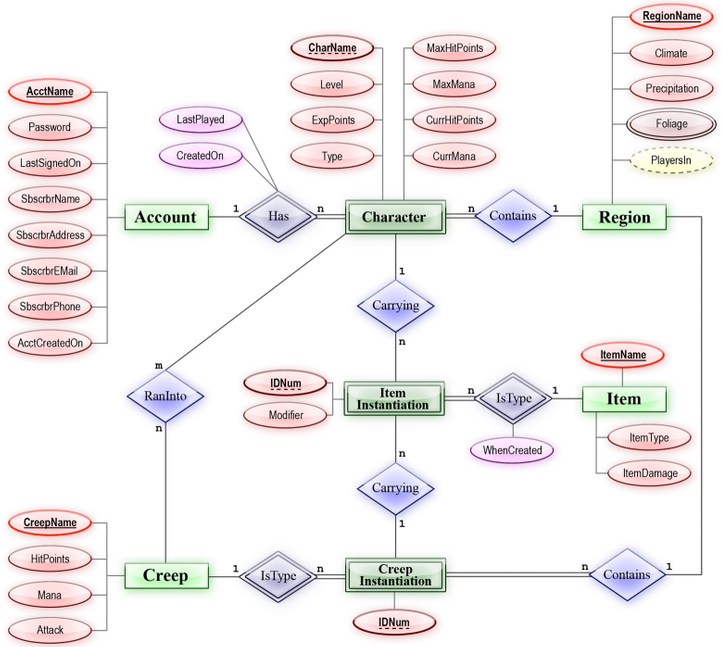
The Data Analysis Pipeline



Structuring Data for Analysis

Database vs Flat File

Database



Flat File

A1 season

	A	B	C	D	E	F	G	H	I	J	K	L
1	season	size	speed	mxPH	mnO2	Cl	NO3	NH4	oPO4	PO4	Chla	a1
2	winter	small	medium	8	9.8	60.8	6.238	578	105	170	50	0
3	spring	small	medium	8.35	8	57.75	1.288	370	428.75	558.75	1.3	1.4
4	autumn	small	medium	8.1	11.4	40.02	5.33	346.66699	125.667	187.05701	15.6	3.3
5	spring	small	medium	8.07	4.8	77.364	2.302	98.182	61.182	138.7	1.4	3.1
6	autumn	small	medium	8.06	9	55.35	10.416	233.7	58.222	97.58	10.5	9.2
7	winter	small	high	8.25	13.1	65.75	9.248	430	18.25	56.667	28.4	15.1
8	summer	small	high	8.15	10.3	73.25	1.535	110	61.25	111.75	3.2	2.4
9	autumn	small	high	8.05	10.6	59.067	4.99	205.66701	44.667	77.434	6.9	18.2
10	winter	small	medium	8.7	3.4	21.95	0.886	102.75	36.3	71	5.544	25.4
11	winter	small	high	7.93	9.9	8	1.39	5.8	27.25	46.6	0.8	17
12	spring	small	high	7.7	10.2	8	1.527	21.571	12.75	20.75	0.8	16.6
13	summer	small	high	7.45	11.7	8.69	1.588	18.429	10.667	19	0.6	32.1
14	winter	small	high	7.74	9.6	5	1.223	27.286	12	17	41	43.5
15	summer	small	high	7.72	11.8	6.3	1.47	8	16	15	0.5	31.1
16	winter	small	high	7.9	9.6	3	1.448	46.2	13	61.6	0.3	52.2
17	autumn	small	high	7.55	11.5	4.7	1.32	14.75	4.25	98.25	1.1	69.9
18	winter	small	high	7.78	12	7	1.42	34.333	18.667	50	1.1	46.2
19	spring	small	high	7.61	9.8	7	1.443	31.333	20	57.833	0.4	31.8
20	summer	small	high	7.35	10.4	7	1.718	49	41.5	61.5	0.8	50.6
21	spring	small	medium	7.79	3.2	64	2.822	8777.59961	564.59998	771.59998	4.5	0
22	winter	small	medium	7.83	10.7	88	4.825	1729	467.5	586	16	0
23	spring	small	high	7.2	9.2	0.8	0.642	81	15.6	18	0.5	15.5
24	autumn	small	high	7.75	10.3	32.92	2.942	42	16	40	7.6	23.2
25	winter	small	high	7.62	8.5	11.867	1.715	208.33299	3	27.5	1.7	74.2
26	spring	small	high	7.84	9.4	10.975	1.51	12.5	3	11.5	1.5	13
27	summer	small	high	7.77	10.7	12.536	3.976	58.5	9	44.136	3	4.1
28	winter	small	high	7.09	8.4	10.5	1.572	28	4	13.6	0.5	29.7
29	autumn	small	high	6.8	11.1	9	0.63	20	4	NA	2.7	30.3
30	winter	small	high	8	9.8	16	0.73	20	26	45	0.8	17.1

Data Integrity

Data Analysis

Rows vs Columns

Columns contain attributes (variables, fields, etc.)

Rows contain objects*

A1 season

	A	B	C	D	E	F	G	H	I	J	K	L
1	season	size	speed	mxPH	mnO2	Cl	NO3	NH4	oPO4	PO4	Chla	a1
2	winter	small	medium	8	9.8	60.8	6.238	578	105	170	50	0
3	spring	small	medium	8.35	8	57.75	1.288	370	428.75	558.75	1.3	1.4
4	autumn	small	medium	8.1	11.4	40.02	5.33	346.66699	125.667	187.05701	15.6	3.3
5	spring	small	medium	8.07	4.8	77.364	2.302	98.182	61.182	138.7	1.4	3.1
6	autumn	small	medium	8.06	9	55.35	10.416	233.7	58.222	97.58	10.5	9.2
7	winter	small	high	8.25	13.1	65.75	9.248	430	18.25	56.667	28.4	15.1
8	summer	small	high	8.15	10.3	73.25	1.535	110	61.25	111.75	3.2	2.4
9	autumn	small	high	8.05	10.6	59.067	4.99	205.66701	44.667	77.434	6.9	18.2
10	winter	small	medium	8.7	3.4	21.95	0.886	102.75	36.3	71	5.544	25.4
11	winter	small	high	7.93	9.9	8	1.39	5.8	27.25	46.6	0.8	17
12	spring	small	high	7.7	10.2	8	1.527	21.571	12.75	20.75	0.8	16.6
13	summer	small	high	7.45	11.7	8.69	1.588	18.429	10.667	19	0.6	32.1
14	winter	small	high	7.74	9.6	5	1.223	27.286	12	17	41	43.5
15	summer	small	high	7.72	11.8	6.3	1.47	8	16	15	0.5	31.1
16	winter	small	high	7.9	9.6	3	1.448	46.2	13	61.6	0.3	52.2
17	autumn	small	high	7.55	11.5	4.7	1.32	14.75	4.25	98.25	1.1	69.9
18	winter	small	high	7.78	12	7	1.42	34.333	18.667	50	1.1	46.2
19	spring	small	high	7.61	9.8	7	1.443	31.333	20	57.833	0.4	31.8
20	summer	small	high	7.35	10.4	7	1.718	49	41.5	61.5	0.8	50.6
21	spring	small	medium	7.79	3.2	64	2.822	8777.59961	564.59998	771.59998	4.5	0
22	winter	small	medium	7.83	10.7	88	4.825	1729	467.5	586	16	0
23	spring	small	high	7.2	9.2	0.8	0.642	81	15.6	18	0.5	15.5
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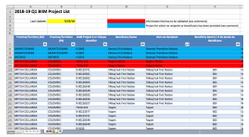
30	winter	small	high	8	9.8	16	0.73	20	26	45	0.8	17.1



Rows vs Columns

variable (field) name

object ID

variable (field) value (datum)

A1 season

	A	B	C	D	E	F	G	H	I	J	K	L
1	season	size	speed	mxPH	mnO2	Cl	NO3	NH4	oPO4	PO4	Chla	a1
2	winter	small	medium	8	9.8	60.8	6.238	578	105	170	50	0
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4	autumn	small	medium	8.1	11.4	40.02	5.33	346.66699	125.667	187.05701	15.6	3.3
5	spring	small	medium	8.07	4.8	77.364	2.302	98.182	61.182	138.7	1.4	3.1
6	autumn	small	medium	8.06	9	55.35	10.416	233.7	58.222	97.58	10.5	9.2
7	winter	small	high	8.25	13.1	65.75	9.248	430	18.25	56.667	28.4	15.1
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18	winter	small	high	7.78	12	7	1.42	34.333	18.667	50	1.1	46.2
19	spring	small	high	7.61	9.8	7	1.443	31.333	20	57.833	0.4	31.8
20	summer	small	high	7.35	10.4	7	1.718	49	41.5	61.5	0.8	50.6
21	spring	small	medium	7.79	3.2	64	2.822	8777.59961	564.59998	771.59998	4.5	0
22	winter	small	medium	7.83	10.7	88	4.825	1729	467.5	586	16	0
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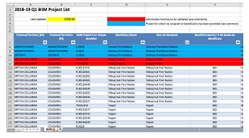
29	autumn	small	high	6.8	11.1	9	0.63	20	4	NA	2.7	30.3
30	winter	small	high	8	9.8	16	0.73	20	26	45	0.8	17.1

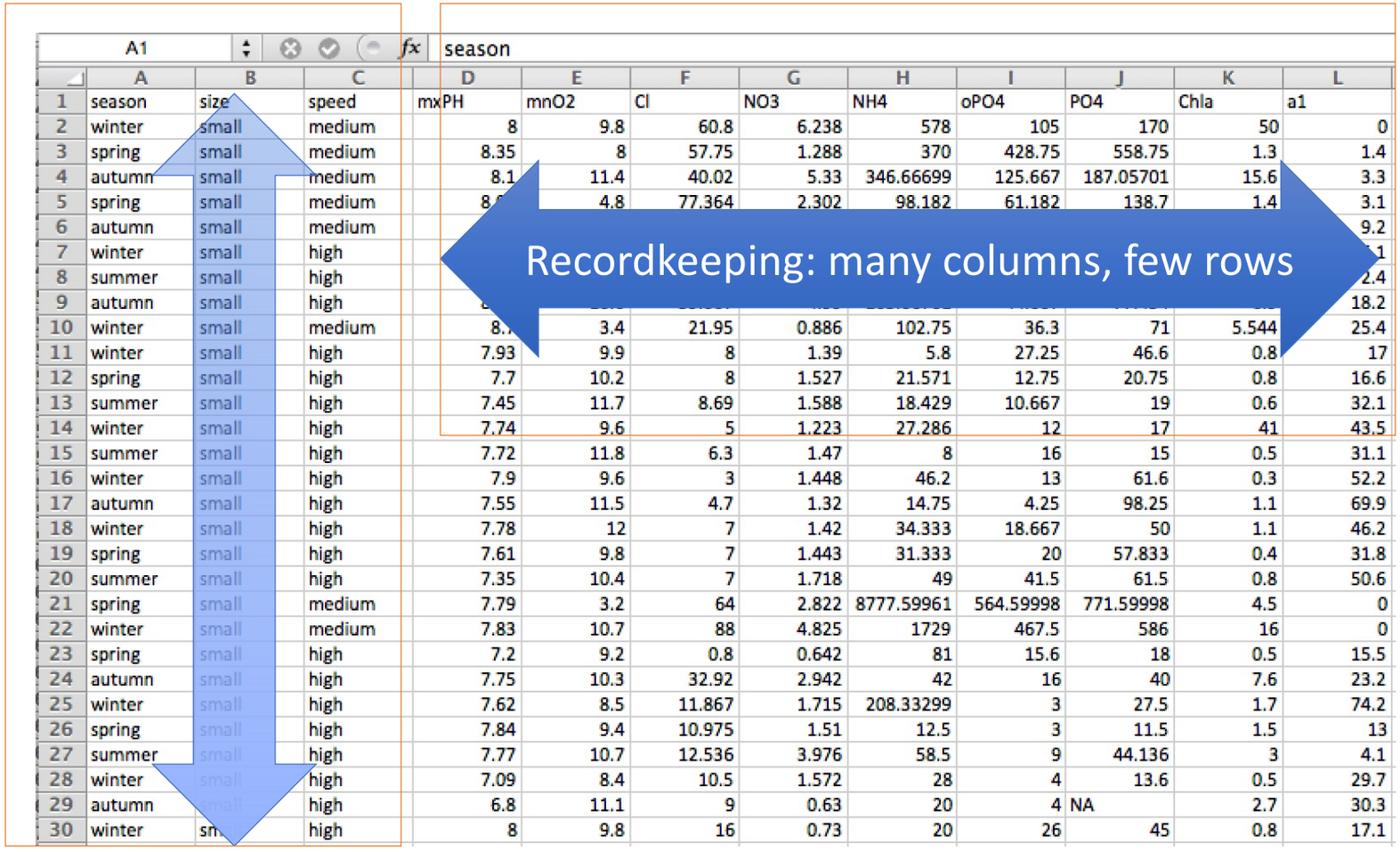
Record-keeping

Research



Dataset Shape and Focus

Research: many rows, few columns



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5	spring	small	medium	8.	4.8	77.364	2.302	98.182	61.182	138.7	1.4	3.1
6	autumn	small	medium									9.2
7	winter	small	high									.1
8	summer	small	high									2.4
9	autumn	small	high									18.2
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21	spring	small	medium	7.79	3.2	64	2.822	8777.59961	564.59998	771.59998	4.5	0
22	winter	small	medium	7.83	10.7	88	4.825	1729	467.5	586	16	0
23	spring	small	high	7.2	9.2	0.8	0.642	81	15.6	18	0.5	15.5
24	autumn	small	high	7.75	10.3	32.92	2.942	42	16	40	7.6	23.2
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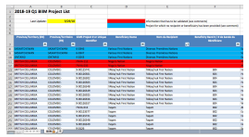
28	winter	small	high	7.09	8.4	10.5	1.572	28	4	13.6	0.5	29.7
29	autumn	small	high	6.8	11.1	9	0.63	20	4	NA	2.7	30.3
30	winter	sm	high	8	9.8	16	0.73	20	26	45	0.8	17.1

Record-keeping

Research



Data Preparation for Analysis

Validating, Cleaning, Augmenting, Transforming

Data Preparation

- Data validation + verification
- Data cleaning
- Data transformation
- (Data Exploration?)

Data Preparation

- Data validation + verification
- Data cleaning
- Data transformation
- (Data Exploration?)

Each of these steps may themselves involve data analysis and other techniques

Data Validation + Verification

- **Verification**: Confirm that the data is correct relative to the dataset
- **Validation**: Confirm that the data correctly represents the objects
- We determine data cleaning requirements based on the results of our data verification and validation

[3, 10.43, ROUn, golden delicious]

Data Cleaning

A question for you: **should you clean before you do exploratory analysis?**

Some possible issues:

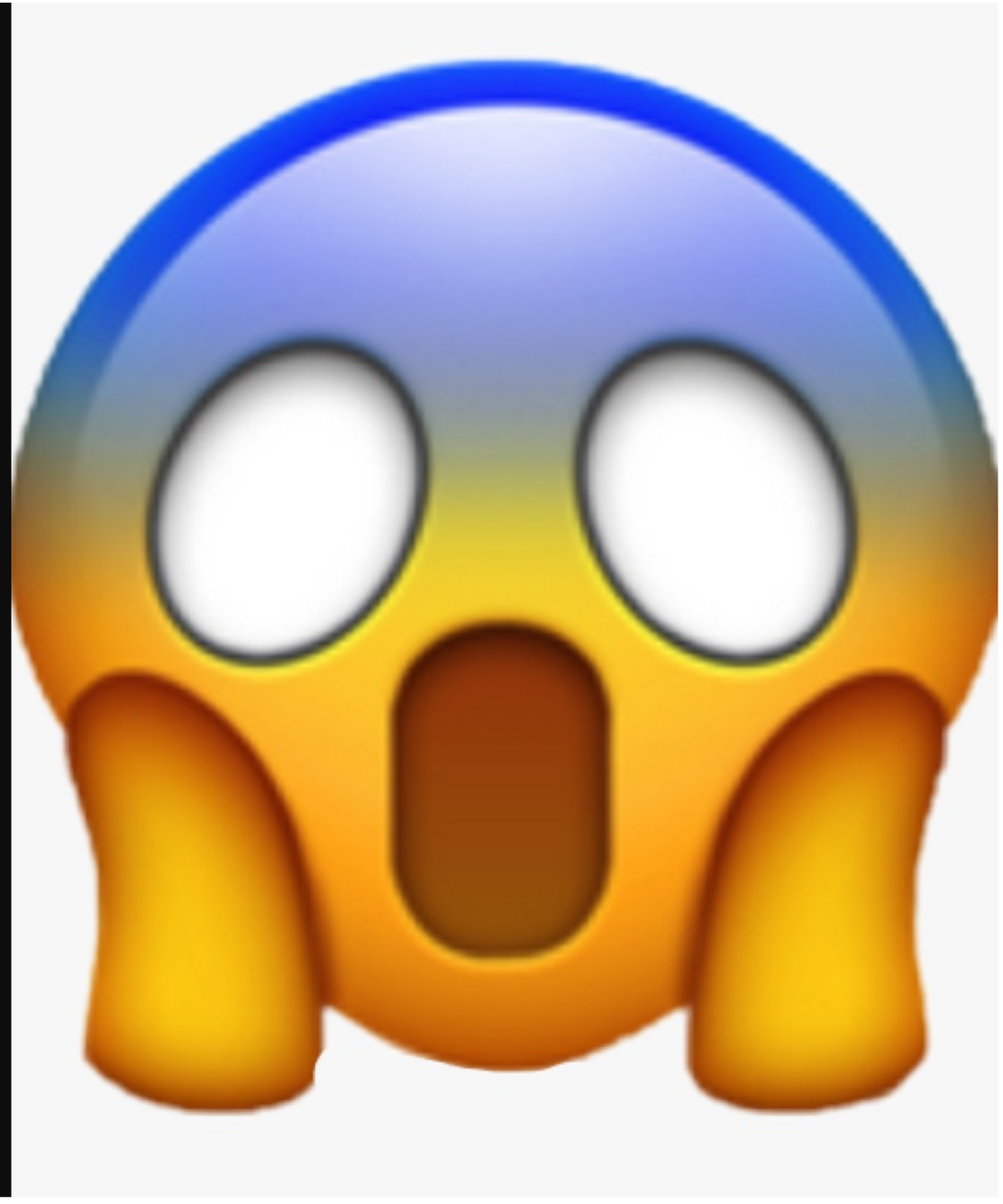
- Character encodings
- Missing Data
- Data collection or entry errors
- Systematic errors

The Curse of Free Text Fields

- The curse of categorical data is made much worse by the curse of free text fields

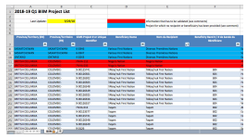
- If you have a field that is supposed to be categorical but it is a free text field, **it is no longer categorical**

- You can use machine learning techniques to help to some extent, but this is a case **where an ounce or prevention is worth a pound of cure**.



Data Cleaning Bingo

random missing values	outliers	values outside of expected range - numeric	factors incorrectly/iconsistently coded	date/time values in multiple formats
impossible numeric values	leading or trailing white space	badly formatted date/time values	non-random missing values	logical inconsistencies across fields
characters in numeric field	values outside of expected range - date/time	DCB!	inconsistent or no distinction between null, 0,not available, not applicable,missing	possible factors missing
multiple symbols used for missing values	???	fields incorrectly separated in row	blank fields	logical iconsistencies within field
entire blank rows	character encoding issues	duplicate value in unique field	non-factor values in factor	numeric values in character field



Cleaning: Character Encodings

The ASCII code

American Standard Code for Information Interchange

ASCII control characters

DEC	HEX	Simbolo ASCII	
00	00h	NULL	(carácter nulo)
01	01h	SOH	(inicio encabezado)
02	02h	STX	(inicio texto)
03	03h	ETX	(fin de texto)
04	04h	EOT	(fin transmisión)
05	05h	ENQ	(enquiry)
06	06h	ACK	(acknowledgement)
07	07h	BEL	(timbre)
08	08h	BS	(retroceso)
09	09h	HT	(tab horizontal)
10	0Ah	LF	(salto de linea)
11	0Bh	VT	(tab vertical)
12	0Ch	FF	(form feed)
13	0Dh	CR	(retorno de carro)
14	0Eh	SO	(shift Out)
15	0Fh	SI	(shift In)
16	10h	DLE	(data link escape)
17	11h	DC1	(device control 1)
18	12h	DC2	(device control 2)
19	13h	DC3	(device control 3)
20	14h	DC4	(device control 4)
21	15h	NAK	(negative acknowle.)
22	16h	SYN	(synchronous idle)
23	17h	ETB	(end of trans. block)
24	18h	CAN	(cancel)
25	19h	EM	(end of medium)
26	1Ah	SUB	(substitute)
27	1Bh	ESC	(escape)
28	1Ch	FS	(file separator)
29	1Dh	GS	(group separator)
30	1Eh	RS	(record separator)
31	1Fh	US	(unit separator)
127	20h	DEL	(delete)

ASCII printable characters

DEC	HEX	Simbolo	DEC	HEX	Simbolo	DEC	HEX	Simbolo
32	20h	espacio	64	40h	@	96	60h	`
33	21h	!	65	41h	A	97	61h	a
34	22h	"	66	42h	B	98	62h	b
35	23h	#	67	43h	C	99	63h	c
36	24h	$	68	44h	D	100	64h	d
37	25h	%	69	45h	E	101	65h	e
38	26h	&	70	46h	F	102	66h	f
39	27h	'	71	47h	G	103	67h	g
40	28h	(	72	48h	H	104	68h	h
41	29h	)	73	49h	I	105	69h	i
42	2Ah	*	74	4Ah	J	106	6Ah	j
43	2Bh	+	75	4Bh	K	107	6Bh	k
44	2Ch	,	76	4Ch	L	108	6Ch	l
45	2Dh	-	77	4Dh	M	109	6Dh	m
46	2Eh	.	78	4Eh	N	110	6Eh	n
47	2Fh	/	79	4Fh	O	111	6Fh	o
48	30h	0	80	50h	P	112	70h	p
49	31h	1	81	51h	Q	113	71h	q
50	32h	2	82	52h	R	114	72h	r
51	33h	3	83	53h	S	115	73h	s
52	34h	4	84	54h	T	116	74h	t
53	35h	5	85	55h	U	117	75h	u
54	36h	6	86	56h	V	118	76h	v
55	37h	7	87	57h	W	119	77h	w
56	38h	8	88	58h	X	120	78h	x
57	39h	9	89	59h	Y	121	79h	y
58	3Ah	:	90	5Ah	Z	122	7Ah	z
59	3Bh	;	91	5Bh	[	123	7Bh	{
60	3Ch	<	92	5Ch	\	124	7Ch	|
61	3Dh	=	93	5Dh	]	125	7Dh	}
62	3Eh	>	94	5Eh	^	126	7Eh	~
63	3Fh	?	95	5Fh	_			

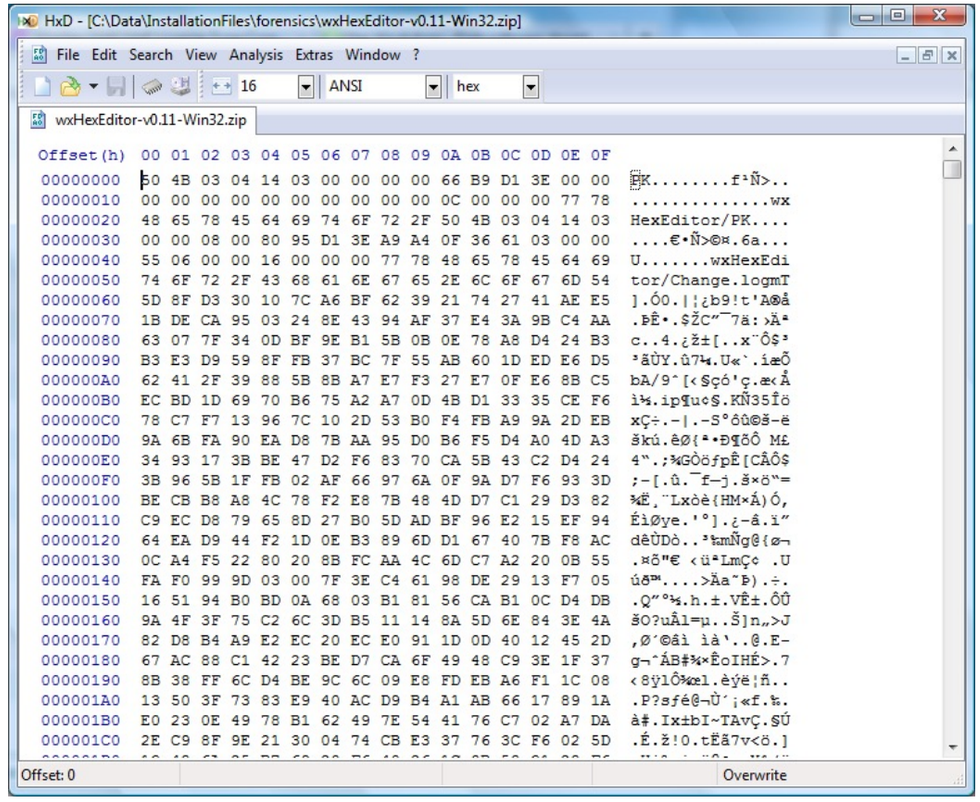
theASCIIcode.com.ar

Extended ASCII characters

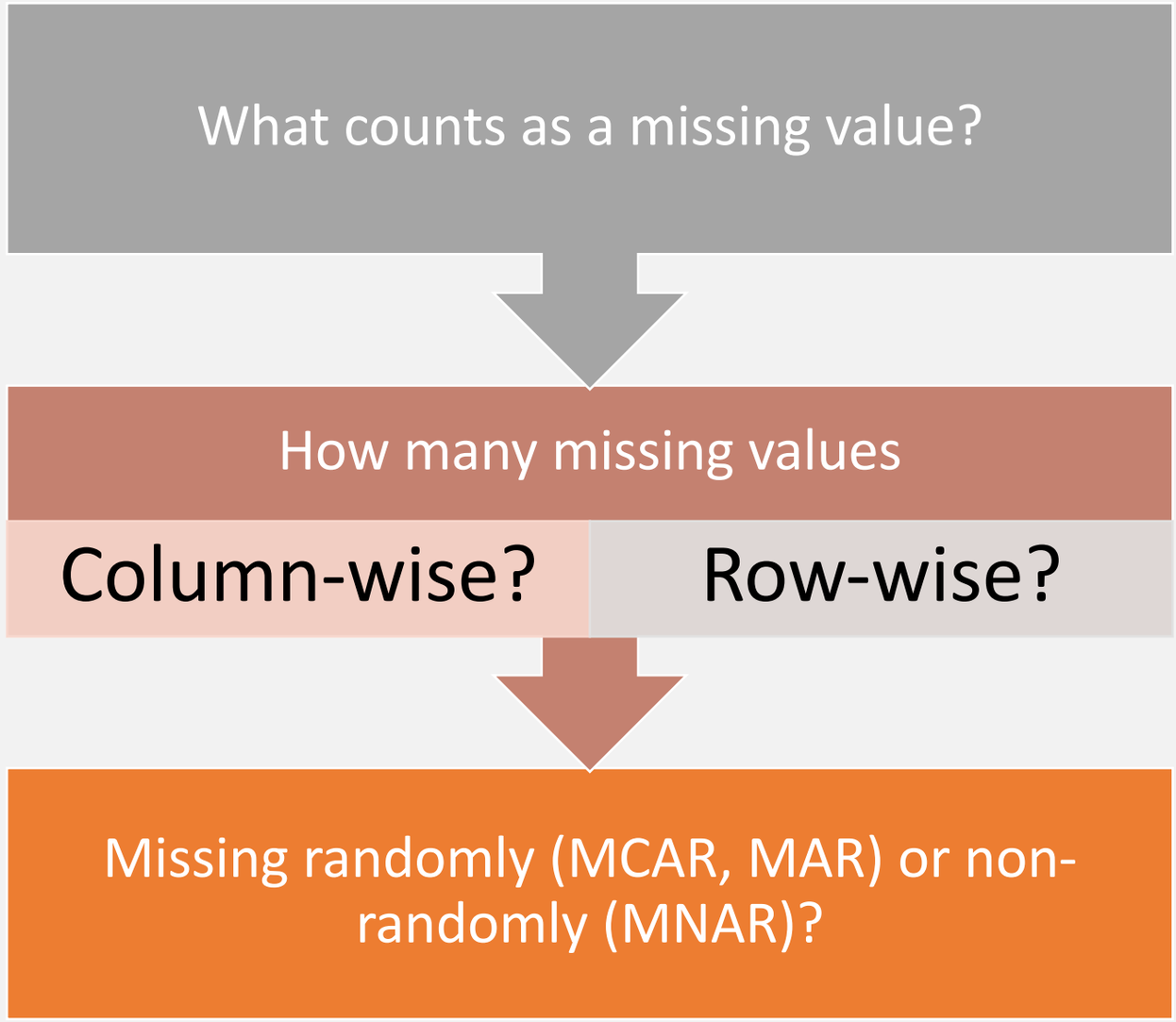
DEC	HEX	Simbolo	DEC	HEX	Simbolo	DEC	HEX	Simbolo	DEC	HEX	Simbolo
128	80h	Ç	160	A0h	á	192	C0h	└	224	E0h	Ó
129	81h	ü	161	A1h	í	193	C1h	┴	225	E1h	ß
130	82h	é	162	A2h	ó	194	C2h	┬	226	E2h	Ô
131	83h	â	163	A3h	ú	195	C3h	├	227	E3h	Ò
132	84h	ä	164	A4h	ñ	196	C4h	─	228	E4h	õ
133	85h	à	165	A5h	Ñ	197	C5h	┼	229	E5h	Õ
134	86h	å	166	A6h	ª	198	C6h	ã	230	E6h	µ
135	87h	ç	167	A7h	º	199	C7h	Ã	231	E7h	þ
136	88h	ê	168	A8h	¿	200	C8h	╚	232	E8h	Þ
137	89h	ë	169	A9h	®	201	C9h	╔	233	E9h	Ú
138	8Ah	è	170	AAh	¬	202	CAh	╩	234	EAh	Û
139	8Bh	ï	171	ABh	½	203	CBh	╦	235	EBh	Ù
140	8Ch	î	172	ACh	¼	204	CCh	╠	236	ECh	ý
141	8Dh	ì	173	ADh	¡	205	CDh	═	237	EDh	Ý
142	8Eh	Ä	174	AEh	«	206	CEh	╬	238	EEh	¯
143	8Fh	Å	175	AFh	»	207	CFh	¤	239	EFh	´
144	90h	É	176	B0h	░	208	D0h	ð	240	F0h	
145	91h	æ	177	B1h	▒	209	D1h	Ð	241	F1h	±
146	92h	Æ	178	B2h	▓	210	D2h	Ê	242	F2h	‗
147	93h	ô	179	B3h	│	211	D3h	Ë	243	F3h	¾
148	94h	ò	180	B4h	┤	212	D4h	È	244	F4h	¶
149	95h	ò	181	B5h	Á	213	D5h	ı	245	F5h	§
150	96h	û	182	B6h	Â	214	D6h	Í	246	F6h	÷
151	97h	ù	183	B7h	À	215	D7h	Î	247	F7h	¸
152	98h	ÿ	184	B8h	©	216	D8h	Ï	248	F8h	°
153	99h	Ö	185	B9h	╣	217	D9h	┘	249	F9h	¨
154	9Ah	Ü	186	BAh	║	218	DAh	┌	250	FAh	·
155	9Bh	ø	187	BBh	╗	219	DBh	█	251	FBh	¹
156	9Ch	£	188	BCh	╝	220	DCh	▄	252	FCh	³
157	9Dh	Ø	189	BDh	¢	221	DDh	¦	253	FDh	²
158	9Eh	×	190	BEh	¥	222	DEh	Ì	254	FEh	■
159	9Fh	ƒ	191	BFh	┐	223	DFh	▀	255	FFh	

Encoding: Tools and Strategies

- Use built in options in text editors, browsers
- Command line tools: iconv, recode, vim
- Libraries in R, Python
- Hex editors
- Statistical methods, machine learning!
- (an ounce of prevention…)



Cleaning: Missing Values



Dealing with Missing Values

If percentage is very low (e.g. <= 5%) you might be able to just ignore those rows*

You can try to detect if the data is MNAR instead of MCAR/MAR using statistical tests

If missing values are MCAR/MAR you might be able to ignore them

You might be able to ‘impute’ the data using statistical modelling techniques

MCAR, MAR, MNAR

Missing Completely At Random (MCAR): Genuinely no pattern to the missing values (think “due to sunspots”

Missing At Random (MAR): Missing values are correlated with another variable you also have.

Missing Not At Random (MNAR): Missing values are correlated with another variable you **don’t** have

Interesting example – fields where people can select “Choose not to reply”

When does imputation make sense?

Cleaning: Other Data Entry Errors

Syntax errors: Capitalization, misspellings

Heaping: people tend to round off measurement values (e.g. hours worked). This results in the data showing up in ‘heaps’

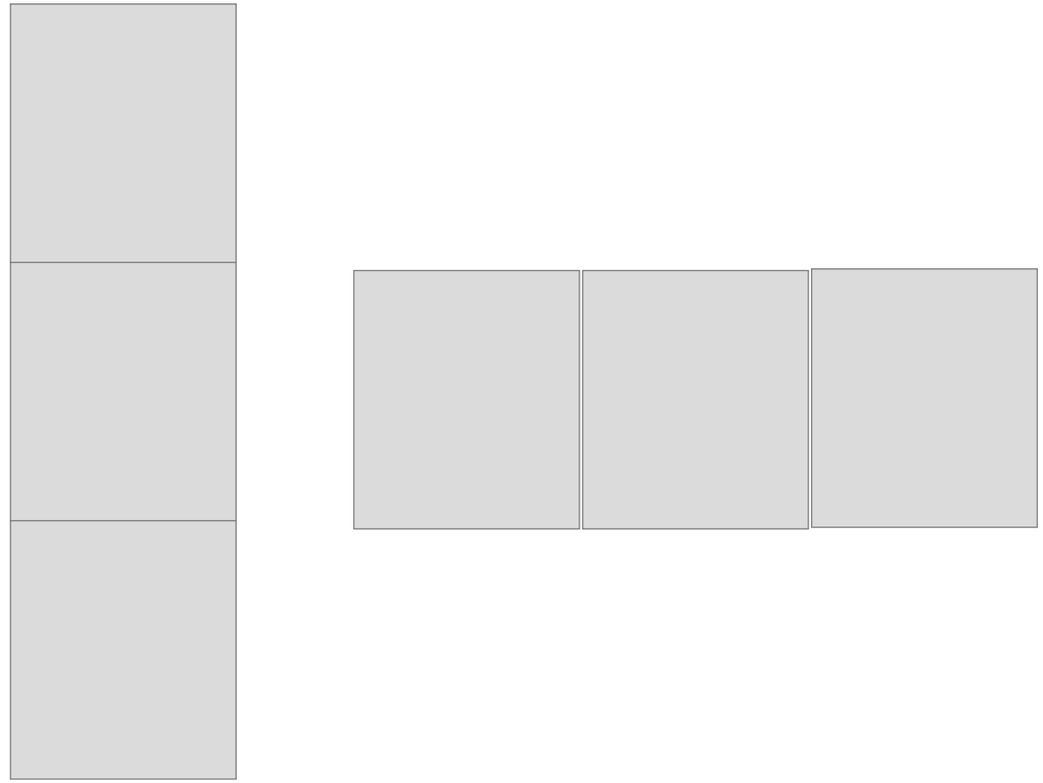
Collector bias, sensor error: recording what is expected rather than what is, dealing with badly calibrated sensor

Transforming Data:

- Changing focus
- Summarizing, condensing
- Reshaping
- Adding complexity and abstraction (metrics)

Long vs Wide Format

- A flat file with the same data can be structured in two shapes:
  - Long (Narrow) (Tall)(Stacked)
  - Wide (Unstacked)
- **Different analysis *algorithms* require particular shapes**
- Presentation of data



Long Format to Wide Format

long

Group#	Group-Size	Status-Check-Time
1	14	START
1	12	MIDDLE
1	13	END
2	20	START
2	5	MIDDLE
2	6	END
3	6	START
3	8	MIDDLE
3	10	END

variable name

variable values

variable name
+ values

wide

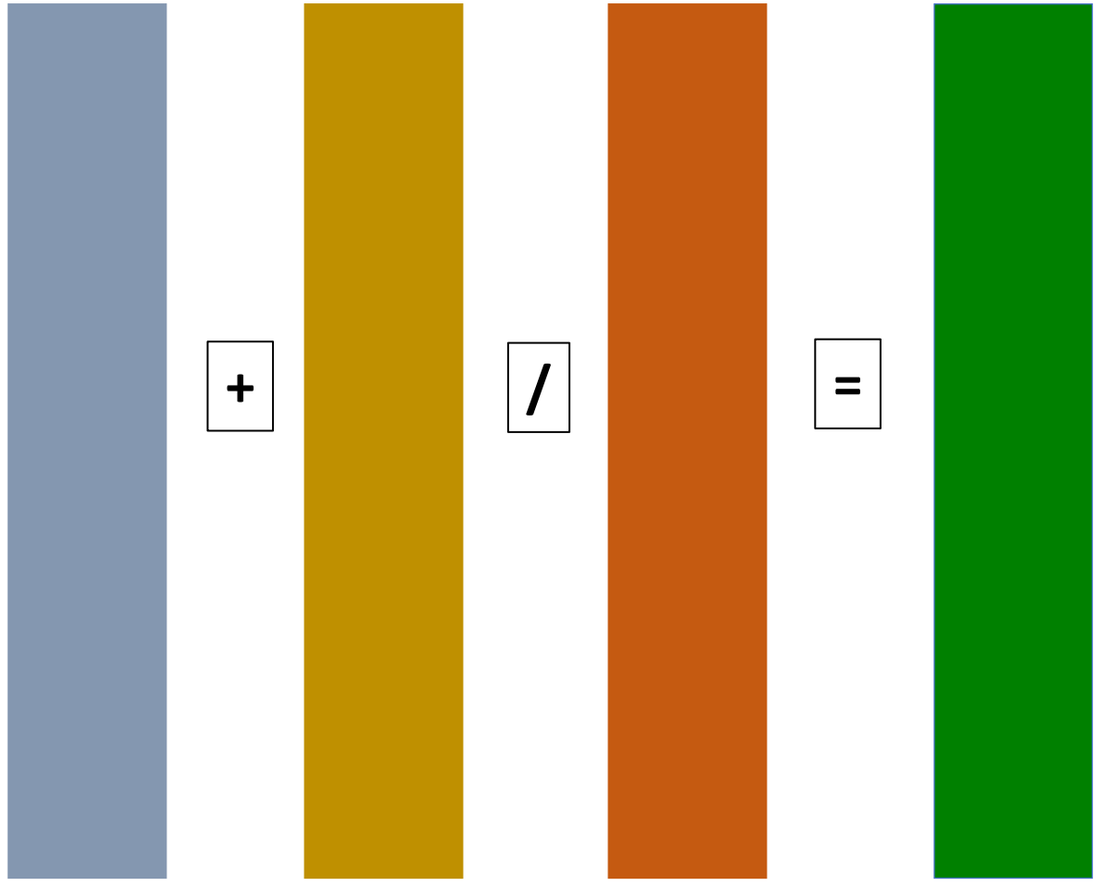
Group#	Group-Size-START	Group-Size-MIDDLE	Group-Size-END
1	14	12	13
2	20	5	6
3	6	8	10

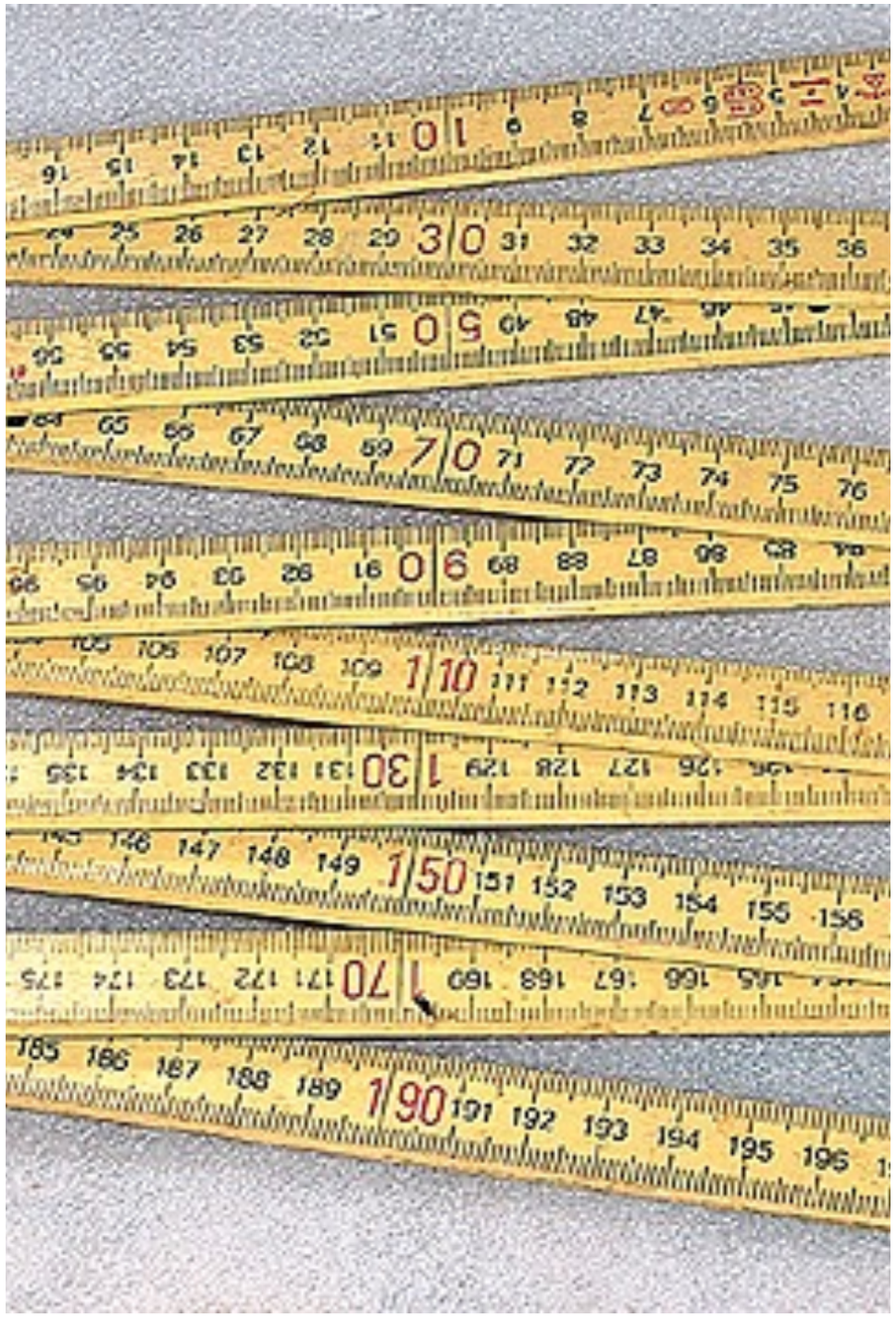
Reshaping Data: Tools

- Reshaping your flat file by hand (or in Excel) can be *extremely* tedious! And error prone!
- This is where tools like R can be extremely helpful and time saving
- Plus – automation. Resist the ‘manual’ short cut!

Adding Complexity: Metrics

- Measures:
  - Concrete properties
  - come from taking measurements
- Metrics:
  - Built up out of measures
  - Quantifies a more abstract concept





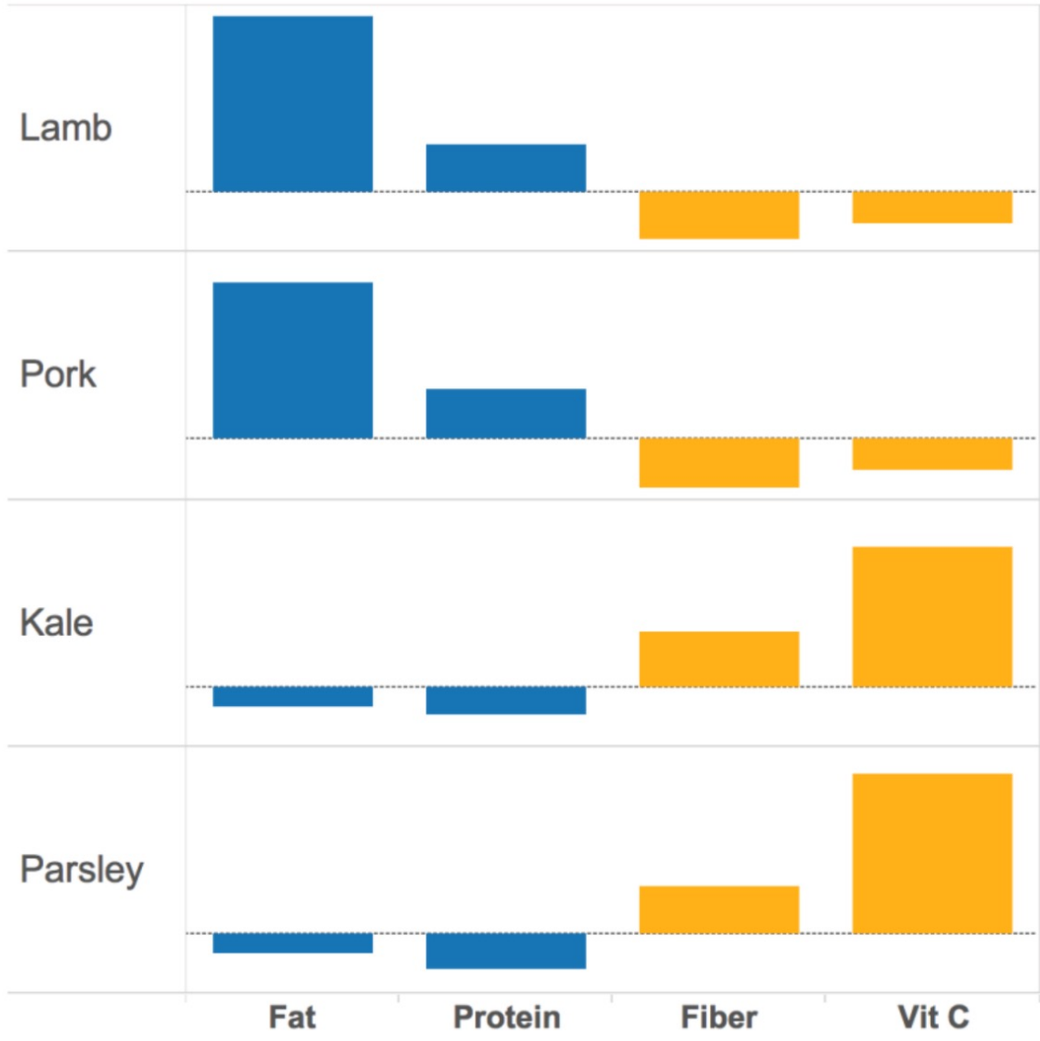
Metrics: Good, Bad, Ugly

- “When a measure becomes a target, it ceases to be a good measure” ***Goodhart’s Law***
- “The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor.” ***Campbell’s Law***

(Surgeons Example)

Data Reduction: Principal Components Analysis (PCA)*

- In this example, presence of nutrients appears to be correlated among food items.
- In the (small) sample consisting of Lamb, Pork, Kale, and Parsley, *Fat* and *Protein* levels seem in step, as do *Fiber* and *Vitamin C*.
- In a larger dataset, the correlations are $r = 0.56$ and $r = 0.57$.
- How much could 2 variables explain?

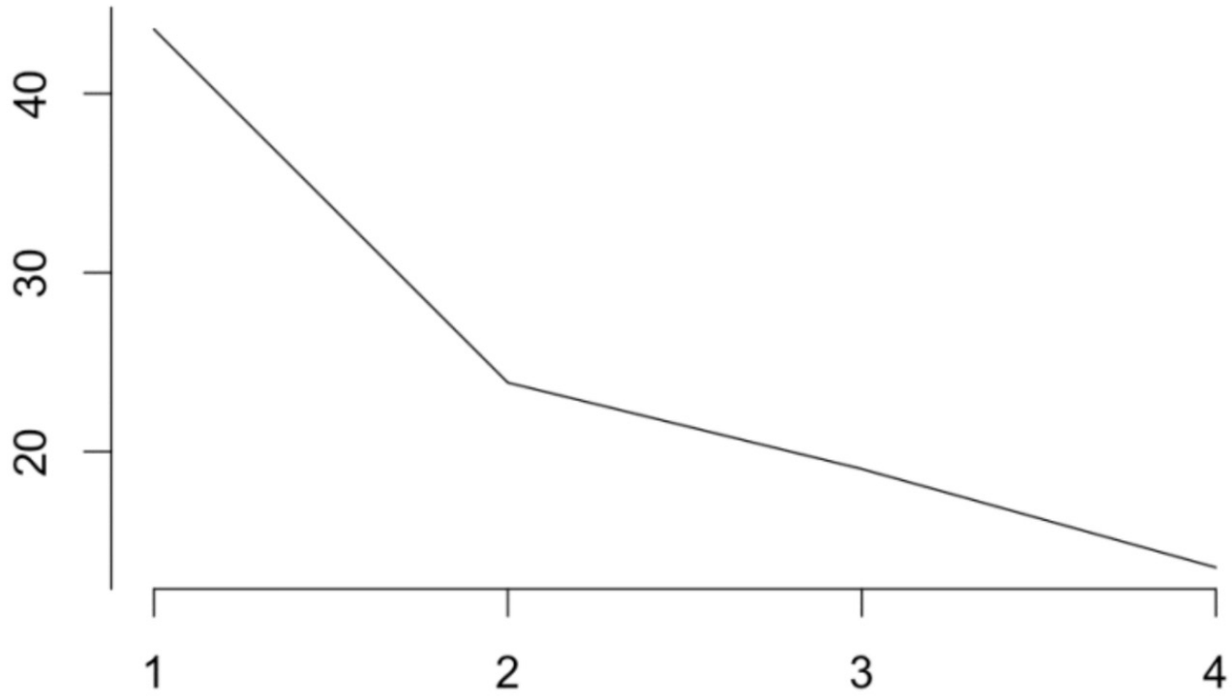


[A. Ng, K. Soo, *Numsense!*, USDA data]

* For categorical variables see also: MCA, FAMD
(https://drbulu.github.io/blog/factorial_methods_part1_overview/)

Retaining Principal Components

- The **proportion of the spread** in the data which can be explained by each principal component is shown in the scree plot.
- How many PCs are retained in the analysis?
  - keep the PCs where the cumulative proportion is below some threshold
  - keep the PCs leading to a kink
- Here, 2 PCs $\approx 68\%$ of the spread.

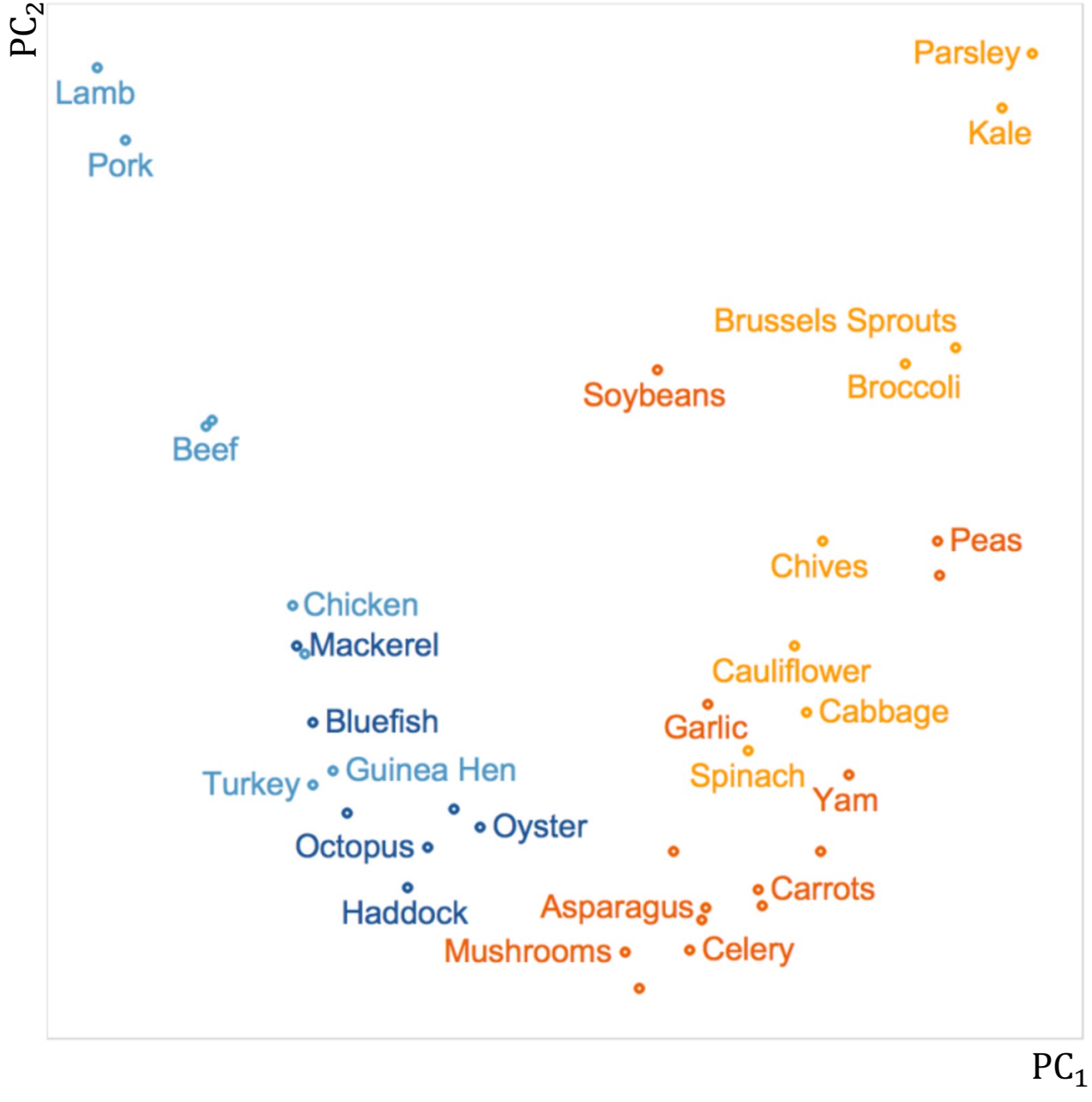


[A. Ng, K. Soo, *Numsense!*, USDA data]

PC_1 differentiates meats from vegetables

PC_2 differentiates **sub-categories** within meats (using *Fat*) and vegetables (using *Vitamin C*).

- Meats are concentrated on the left (low PC_1 values).
- Vegetables are concentrated on the right (high PC_1 values).
- Seafood has lower *Fat* content (low PC_2 values) and is concentrated at the bottom.
- Non-leafy veggies have lower *Vitamin C* content (low PC_2 values) and are also bunched at the bottom.



[A. Ng, K. Soo, *Numsense!*, USDA data]

Are we there yet?