NSF Arctic Data Center

NCEAS learning hub

Intro to Tidy Data

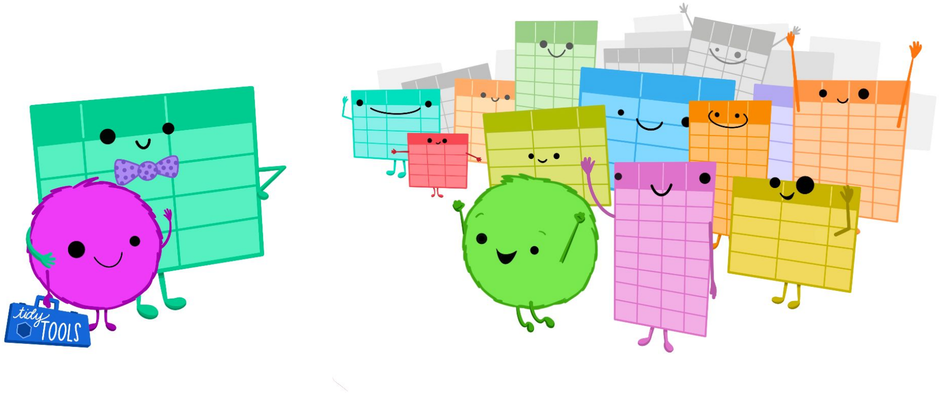
Fundamentals of Qualitative and Quantitative Data Management

2025-01-27

Artwork by @Allison_Horst

Learning Objectives

- Understand basics of relational data models, aka **tidy data**
- Learn how to design and create effective data tables



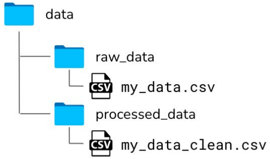
artwork by @allison_horst

Simple Guidelines for Data Management (Borer et al. 2009)

Use a scripted program

~~XLSX~~ TXT CSV Nonproprietary file formats

Keep a raw version of the data

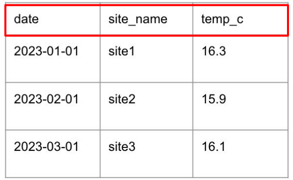


```
data
├── raw_data
│   └── my_data.csv
└── processed_data
    └── my_data_clean.csv
```

```
mooredCTD_site1_2020-2023.txt
mooredCTD_site2_2020-2023.txt
mooredCTD_site3_2020-2023.txt
```

Descriptive names

Header line



date	site_name	temp_c
2023-01-01	site1	16.3
2023-02-01	site2	15.9
2023-03-01	site3	16.1

```
A B C / 1 2 3
```

Plain ASCII text

Simple Guidelines for Data Management (Borer et al. 2009)

- Design your tables to add rows, not columns

- Each column should contain only one type of information

- Record a single piece of data only once; separate information collected at different scales into different tables -- in other words, create a *relational database*

What is tidy data?

Tidy data is a **standardized way of organizing data tables** that allows us to manage and analyze data efficiently, because it **makes it straightforward to understand** the corresponding variable and observation of each value

The Tidy Data Principles

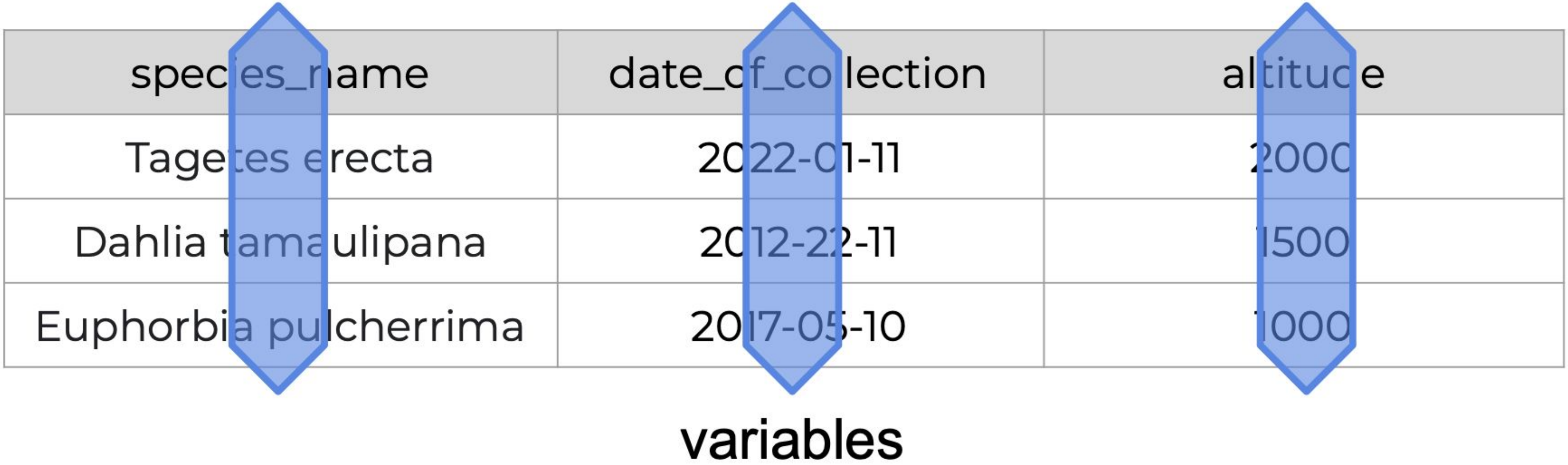
1. Every column is a variable
2. Every row is an observation
3. Every cell is a single value

Tidy Data Building Blocks

Variable: Characteristic that is being measured, counted or described with data.

Example: Car type, salinity, year, mass.

Tidy Data Building Blocks



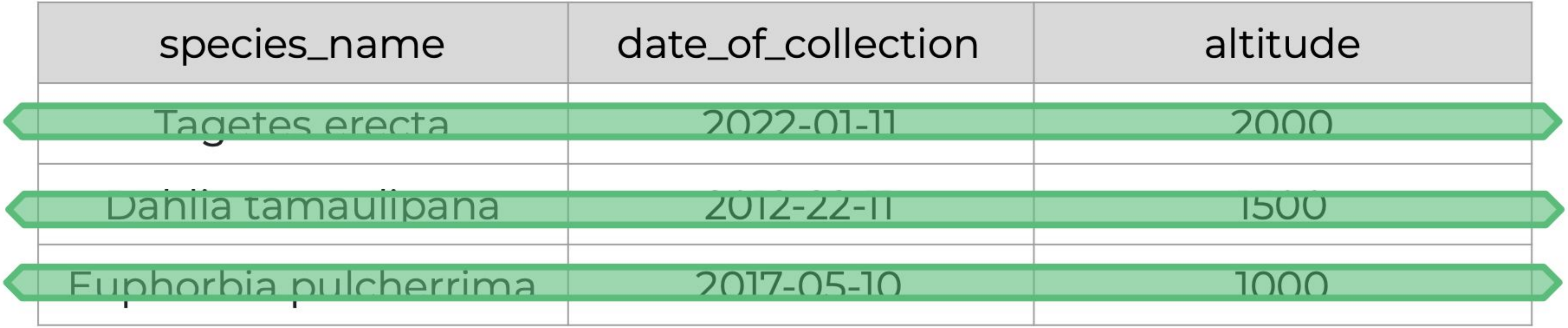
species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

Tidy Data Building Blocks

Observation: a single “data point” for which the measure, count or description of one or more variables is recorded.

Example: If we are collecting data for variables *height*, *species*, and *location* of plants, **each plant is an observation**

Tidy Data Building Blocks



species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

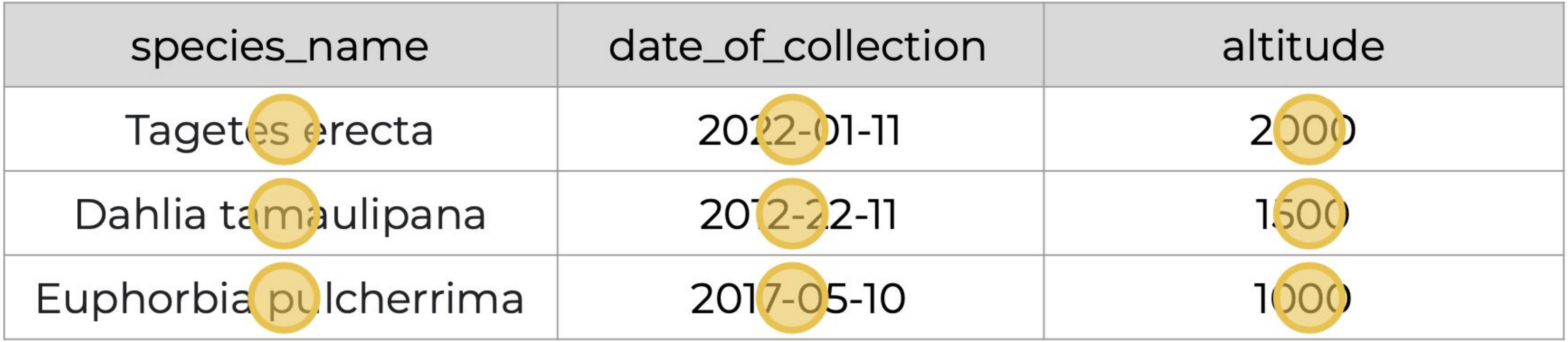
observations

Tidy Data Building Blocks

Value: The record measured, count or description of a variable.

Example: For the variable *height*, **3** (ft) would be the value.

Tidy Data Building Blocks



species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

values

Tidy Data Building Blocks

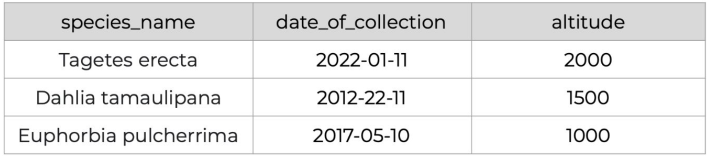
Entity: Each of the types of observation is an entity.

Example: If we collect data for variables: *height*, *species*, *location*, *site_name* for plants and where they are seen, **plant** is an entity and **site** is an entity.

Tidy Data Building Blocks

A dataset is a collection of **values**, with each value belonging to an **observation** and a **variable**.

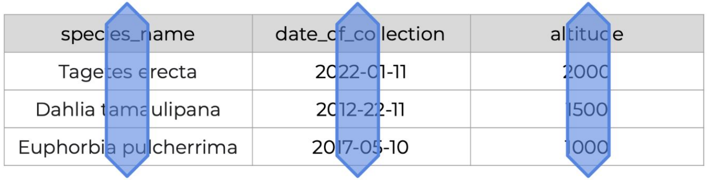
Assessing Tidy Data Principles



species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

tidy data

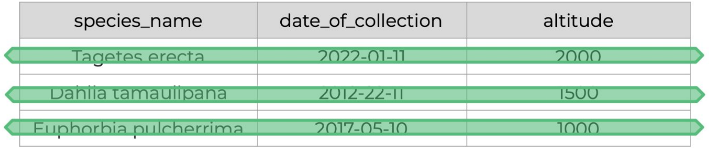
Tidy Data



species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

variables

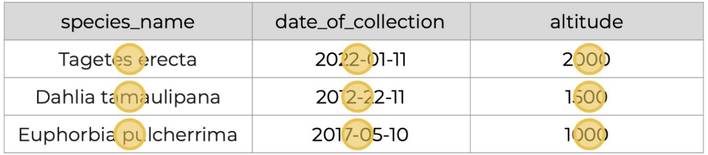
Every column is a variable



species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

observations

Every row is an observation

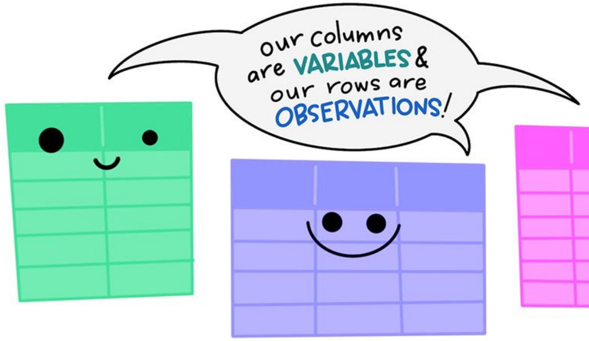


species_name	date_of_collection	altitude
Tagetes erecta	2022-01-11	2000
Dahlia tamaulipana	2012-22-11	1500
Euphorbia pulcherrima	2017-05-10	1000

Every cell is a single values

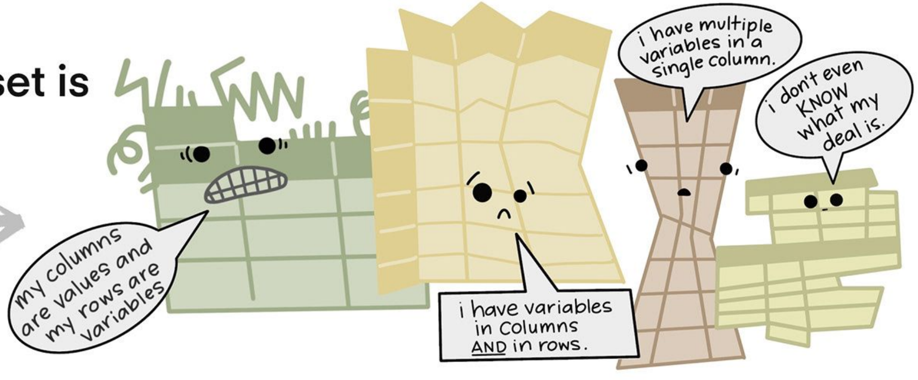
Recognizing “untidy” data

The standard structure of tidy data means that “tidy datasets are all alike...”



“...but every messy dataset is messy in its own way.”

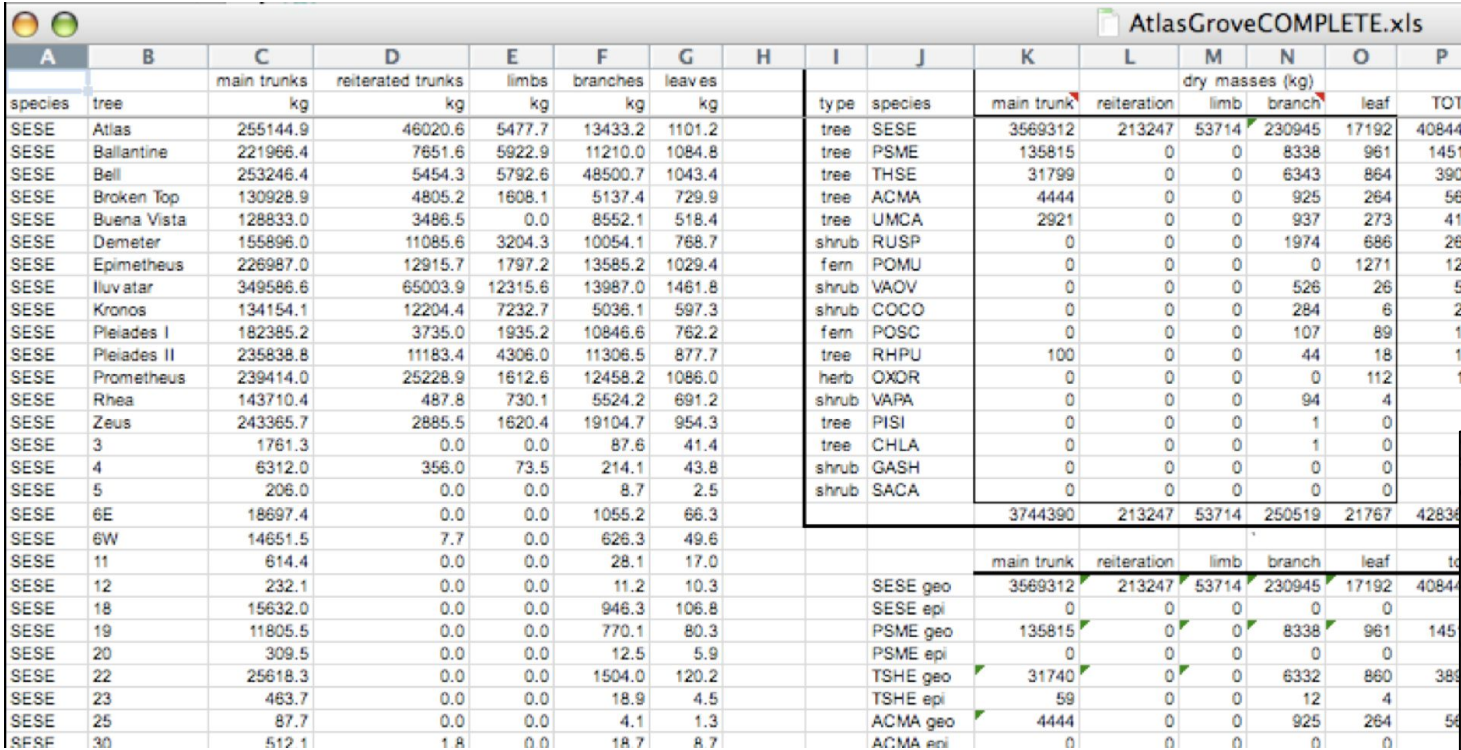
—HADLEY WICKHAM


my columns are values and my rows are variables
i have variables in columns AND in rows.
i have multiple variables in a single column.
i don't even KNOW what my deal is.

artwork by @allison_horst

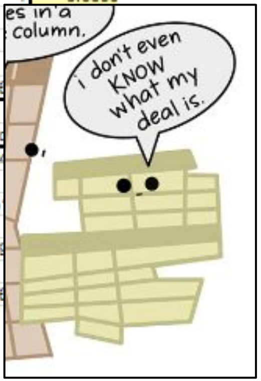
Recognizing “untidy” data

A not-so-tidy spreadsheet received by NCEAS….



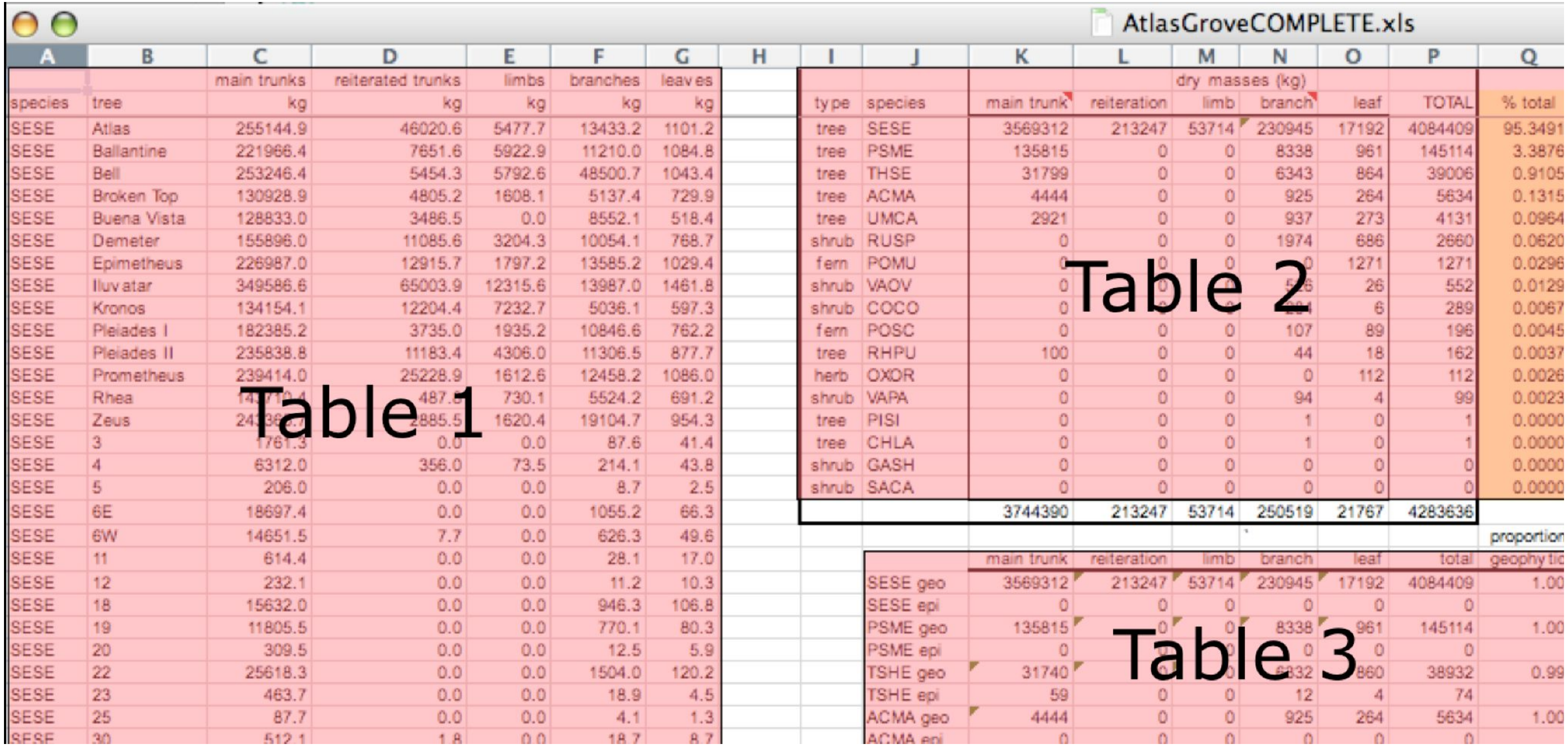
AtlasGroveCOMPLETE.xls

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		main trunks	reiterated trunks	limbs	branches	leav es						dry masses (kg)				
species	tree	kg	kg	kg	kg	kg		ty pe	species	main trunk	reiteration	limb	branch	leaf	TOTAL	% total
SESE	Atlas	255144.9	46020.6	5477.7	13433.2	1101.2		tree	SESE	3569312	213247	53714	230945	17192	4084409	95.3491
SESE	Ballantine	221966.4	7651.6	5922.9	11210.0	1084.8		tree	PSME	135815	0	0	8338	961	145114	3.3876
SESE	Bell	253246.4	5454.3	5792.6	48500.7	1043.4		tree	THSE	31799	0	0	6343	864	39006	0.9105
SESE	Broken Top	130928.9	4805.2	1608.1	5137.4	729.9		tree	ACMA	4444	0	0	925	264	5634	0.1315
SESE	Buena Vista	128833.0	3486.5	0.0	8552.1	518.4		tree	UMCA	2921	0	0	937	273	4131	0.0964
SESE	Demeter	155896.0	11085.6	3204.3	10054.1	768.7		shrub	RUSP	0	0	0	1974	686	2660	0.0620
SESE	Epimetheus	226987.0	12915.7	1797.2	13585.2	1029.4		fern	POMU	0	0	0	0	1271	1271	0.0296
SESE	Iluv atar	349586.6	65003.9	12315.6	13987.0	1461.8		shrub	VAOV	0	0	0	526	26	552	0.0129
SESE	Kronos	134154.1	12204.4	7232.7	5036.1	597.3		shrub	COCO	0	0	0	284	6	289	0.0067
SESE	Pleiades I	182385.2	3735.0	1935.2	10846.6	762.2		fern	POSC	0	0	0	107	89	196	0.0045
SESE	Pleiades II	235838.8	11183.4	4306.0	11306.5	877.7		tree	RHPU	100	0	0	44	18	162	0.0037
SESE	Prometheus	239414.0	25228.9	1612.6	12458.2	1086.0		herb	OXOR	0	0	0	0	112	112	0.0026
SESE	Rhea	143710.4	487.8	730.1	5524.2	691.2		shrub	VAPA	0	0	0	94	4	99	0.0023
SESE	Zeus	243365.7	2885.5	1620.4	19104.7	954.3		tree	PISI	0	0	0	1	0	1	0.0000
SESE	3	1761.3	0.0	0.0	87.6	41.4		tree	CHLA	0	0	0	1	0		
SESE	4	6312.0	356.0	73.5	214.1	43.8		shrub	GASH	0	0	0	0	0		
SESE	5	206.0	0.0	0.0	8.7	2.5		shrub	SACA	0	0	0	0	0		
SESE	6E	18697.4	0.0	0.0	1055.2	66.3				3744390	213247	53714	250519	21767	4283	
SESE	6W	14651.5	7.7	0.0	626.3	49.6										
SESE	11	614.4	0.0	0.0	28.1	17.0				main trunk	reiteration	limb	branch	leaf	to	
SESE	12	232.1	0.0	0.0	11.2	10.3			SESE geo	3569312	213247	53714	230945	17192	40844	
SESE	18	15632.0	0.0	0.0	946.3	106.8			SESE epi	0	0	0	0	0		
SESE	19	11805.5	0.0	0.0	770.1	80.3			PSME geo	135815	0	0	8338	961	145	
SESE	20	309.5	0.0	0.0	12.5	5.9			PSME epi	0	0	0	0	0		
SESE	22	25618.3	0.0	0.0	1504.0	120.2			TSHE geo	31740	0	0	6332	860	389	
SESE	23	463.7	0.0	0.0	18.9	4.5			TSHE epi	59	0	0	12	4		
SESE	25	87.7	0.0	0.0	4.1	1.3			ACMA geo	4444	0	0	925	264	56	
SESE	30	512.1	1.8	0.0	18.7	8.7			ACMA epi	0	0	0	0	0		



Recognizing “untidy” data - multiple tables

Easy for humans to interpret (sort of?), hard for computer programs (e.g. R)



AtlasGroveCOMPLETE.xls

Table 1

A	B	C	D	E	F	G
		main trunks	reiterated trunks	limbs	branches	leaves
species	tree	kg	kg	kg	kg	kg
SESE	Atlas	255144.9	46020.6	5477.7	13433.2	1101.2
SESE	Ballantine	221966.4	7651.6	5922.9	11210.0	1084.8
SESE	Bell	253246.4	5454.3	5792.6	48500.7	1043.4
SESE	Broken Top	130928.9	4805.2	1608.1	5137.4	729.9
SESE	Buena Vista	128833.0	3486.5	0.0	8552.1	518.4
SESE	Demeter	155896.0	11085.6	3204.3	10054.1	768.7
SESE	Epimetheus	226987.0	12915.7	1797.2	13585.2	1029.4
SESE	Iluvatar	349586.6	65003.9	12315.6	13987.0	1461.8
SESE	Kronos	134154.1	12204.4	7232.7	5036.1	597.3
SESE	Pleiades I	182385.2	3735.0	1935.2	10846.6	762.2
SESE	Pleiades II	235838.8	11183.4	4306.0	11306.5	877.7
SESE	Prometheus	239414.0	25228.9	1612.6	12458.2	1086.0
SESE	Rhea	[illegible]	487.5	730.1	5524.2	691.2
SESE	Zeus	[illegible]	2885.5	1620.4	19104.7	954.3
SESE	3	1761.3	0.0	0.0	87.6	41.4
SESE	4	6312.0	356.0	73.5	214.1	43.8
SESE	5	206.0	0.0	0.0	8.7	2.5
SESE	6E	18697.4	0.0	0.0	1055.2	66.3
SESE	6W	14651.5	7.7	0.0	626.3	49.6
SESE	11	614.4	0.0	0.0	28.1	17.0
SESE	12	232.1	0.0	0.0	11.2	10.3
SESE	18	15632.0	0.0	0.0	946.3	106.8
SESE	19	11805.5	0.0	0.0	770.1	80.3
SESE	20	309.5	0.0	0.0	12.5	5.9
SESE	22	25618.3	0.0	0.0	1504.0	120.2
SESE	23	463.7	0.0	0.0	18.9	4.5
SESE	25	87.7	0.0	0.0	4.1	1.3
SESE	30	512.1	1.8	0.0	18.7	8.7

Table 2

I	J	K	L	M	N	O	P	Q
				dry masses (kg)				
type	species	main trunk	reiteration	limb	branch	leaf	TOTAL	% total
tree	SESE	3569312	213247	53714	230945	17192	4084409	95.3491
tree	PSME	135815	0	0	8338	961	145114	3.3876
tree	THSE	31799	0	0	6343	864	39006	0.9105
tree	ACMA	4444	0	0	925	264	5634	0.1315
tree	UMCA	2921	0	0	937	273	4131	0.0964
shrub	RUSP	0	0	0	1974	686	2660	0.0620
fern	POMU	0	0	0	0	1271	1271	0.0296
shrub	VAOV	0	0	0	526	26	552	0.0129
shrub	COCO	0	0	0	[illegible]	6	289	0.0067
fern	POSC	0	0	0	107	89	196	0.0045
tree	RHPU	100	0	0	44	18	162	0.0037
herb	OXOR	0	0	0	0	112	112	0.0026
shrub	VAPA	0	0	0	94	4	99	0.0023
tree	PISI	0	0	0	1	0	1	0.0000
tree	CHLA	0	0	0	1	0	1	0.0000
shrub	GASH	0	0	0	0	0	0	0.0000
shrub	SACA	0	0	0	0	0	0	0.0000
		3744390	213247	53714	250519	21767	4283636	

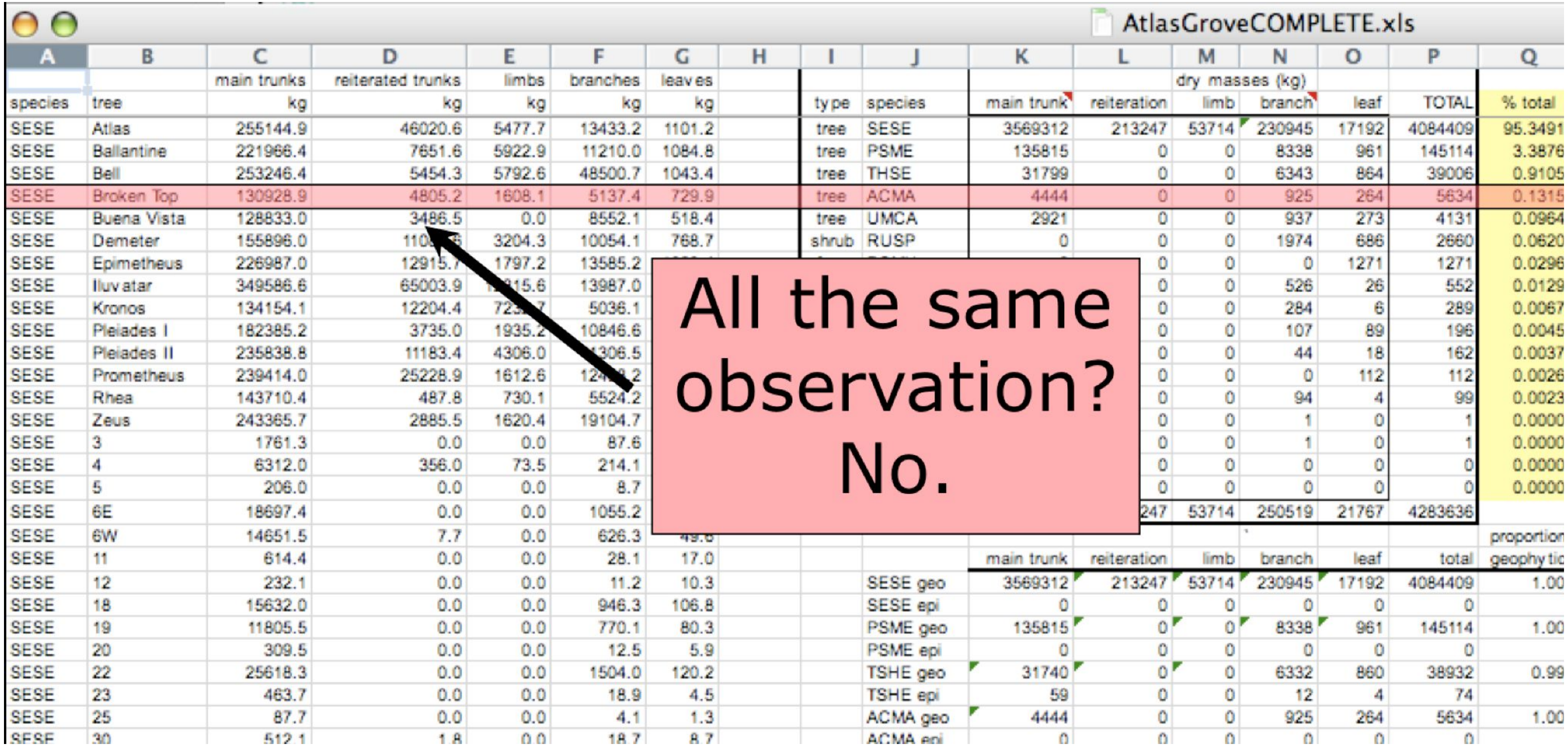
Table 3

J	K	L	M	N	O	P	Q
							proportion
	main trunk	reiteration	limb	branch	leaf	total	geophytic
SESE geo	3569312	213247	53714	230945	17192	4084409	1.00
SESE epi	0	0	0	0	0	0	
PSME geo	135815	0	0	8338	961	145114	1.00
PSME epi	0	0	0	0	0	0	
TSHE geo	31740	0	0	6332	860	38932	0.99
TSHE epi	59	0	0	12	4	74	
ACMA geo	4444	0	0	925	264	5634	1.00
ACMA epi	0	0	0	0	0	0	

INSTEAD: create separate tables/files for each entity measured

Recognizing “untidy” data - inconsistent observations

Each row corresponds to more than one observation



AtlasGroveCOMPLETE.xls

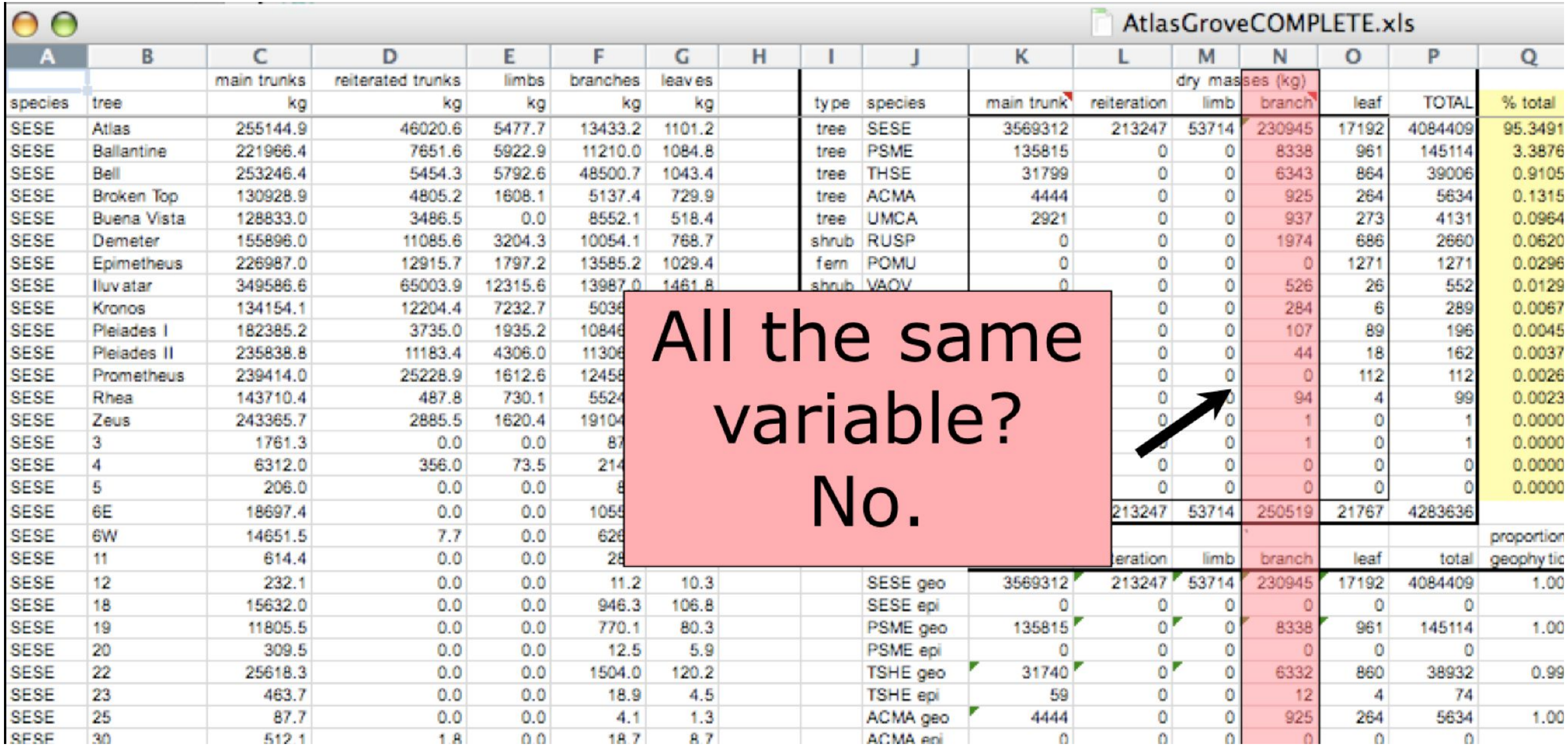
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		main trunks	reiterated trunks	limbs	branches	leaves						dry masses (kg)				
species	tree	kg	kg	kg	kg	kg		type	species	main trunk	reiteration	limb	branch	leaf	TOTAL	% total
SESE	Atlas	255144.9	46020.6	5477.7	13433.2	1101.2		tree	SESE	3569312	213247	53714	230945	17192	4084409	95.3491
SESE	Ballantine	221966.4	7651.6	5922.9	11210.0	1084.8		tree	PSME	135815	0	0	8338	961	145114	3.3876
SESE	Bell	253246.4	5454.3	5792.6	48500.7	1043.4		tree	THSE	31799	0	0	6343	864	39006	0.9105
SESE	Broken Top	130928.9	4805.2	1608.1	5137.4	729.9		tree	ACMA	4444	0	0	925	264	5634	0.1315
SESE	Buena Vista	128833.0	3486.5	0.0	8552.1	518.4		tree	UMCA	2921	0	0	937	273	4131	0.0964
SESE	Demeter	155896.0	[illegible]	3204.3	10054.1	768.7		shrub	RUSP	0	0	0	1974	686	2660	0.0620
SESE	Epimetheus	226987.0	12915.7	1797.2	13585.2	[illegible]		[illegible]	[illegible]	[illegible]	0	0	0	1271	1271	0.0296
SESE	Iluv atar	349586.6	65003.9	[illegible]	13987.0						0	0	526	26	552	0.0129
SESE	Kronos	134154.1	12204.4	[illegible]	5036.1						0	0	284	6	289	0.0067
SESE	Pleiades I	182385.2	3735.0	1935.2	10846.6						0	0	107	89	196	0.0045
SESE	Pleiades II	235838.8	11183.4	4306.0	[illegible]						0	0	44	18	162	0.0037
SESE	Prometheus	239414.0	25228.9	1612.6	[illegible]						0	0	0	112	112	0.0026
SESE	Rhea	143710.4	487.8	730.1	5524.2						0	0	94	4	99	0.0023
SESE	Zeus	243365.7	2885.5	1620.4	19104.7						0	0	1	0	1	0.0000
SESE	3	1761.3	0.0	0.0	87.6						0	0	1	0	1	0.0000
SESE	4	6312.0	356.0	73.5	214.1						0	0	0	0	0	0.0000
SESE	5	206.0	0.0	0.0	8.7						0	0	0	0	0	0.0000
SESE	6E	18697.4	0.0	0.0	1055.2						247	53714	250519	21767	4283636	
SESE	6W	14651.5	7.7	0.0	626.3	[illegible]										proportion
SESE	11	614.4	0.0	0.0	28.1	17.0				main trunk	reiteration	limb	branch	leaf	total	geophy tic
SESE	12	232.1	0.0	0.0	11.2	10.3			SESE geo	3569312	213247	53714	230945	17192	4084409	1.00
SESE	18	15632.0	0.0	0.0	946.3	106.8			SESE epi	0	0	0	0	0	0	
SESE	19	11805.5	0.0	0.0	770.1	80.3			PSME geo	135815	0	0	8338	961	145114	1.00
SESE	20	309.5	0.0	0.0	12.5	5.9			PSME epi	0	0	0	0	0	0	
SESE	22	25618.3	0.0	0.0	1504.0	120.2			TSHE geo	31740	0	0	6332	860	38932	0.99
SESE	23	463.7	0.0	0.0	18.9	4.5			TSHE epi	59	0	0	12	4	74	
SESE	25	87.7	0.0	0.0	4.1	1.3			ACMA geo	4444	0	0	925	264	5634	1.00
SESE	30	512.1	1.8	0.0	18.7	8.7			ACMA epi	0	0	0	0	0	0	

All the same observation? No.

INSTEAD: each row should represent a single observed entity

Recognizing “untidy” data - inconsistent variables

Each column contains more than one variable type



AtlasGroveCOMPLETE.xls

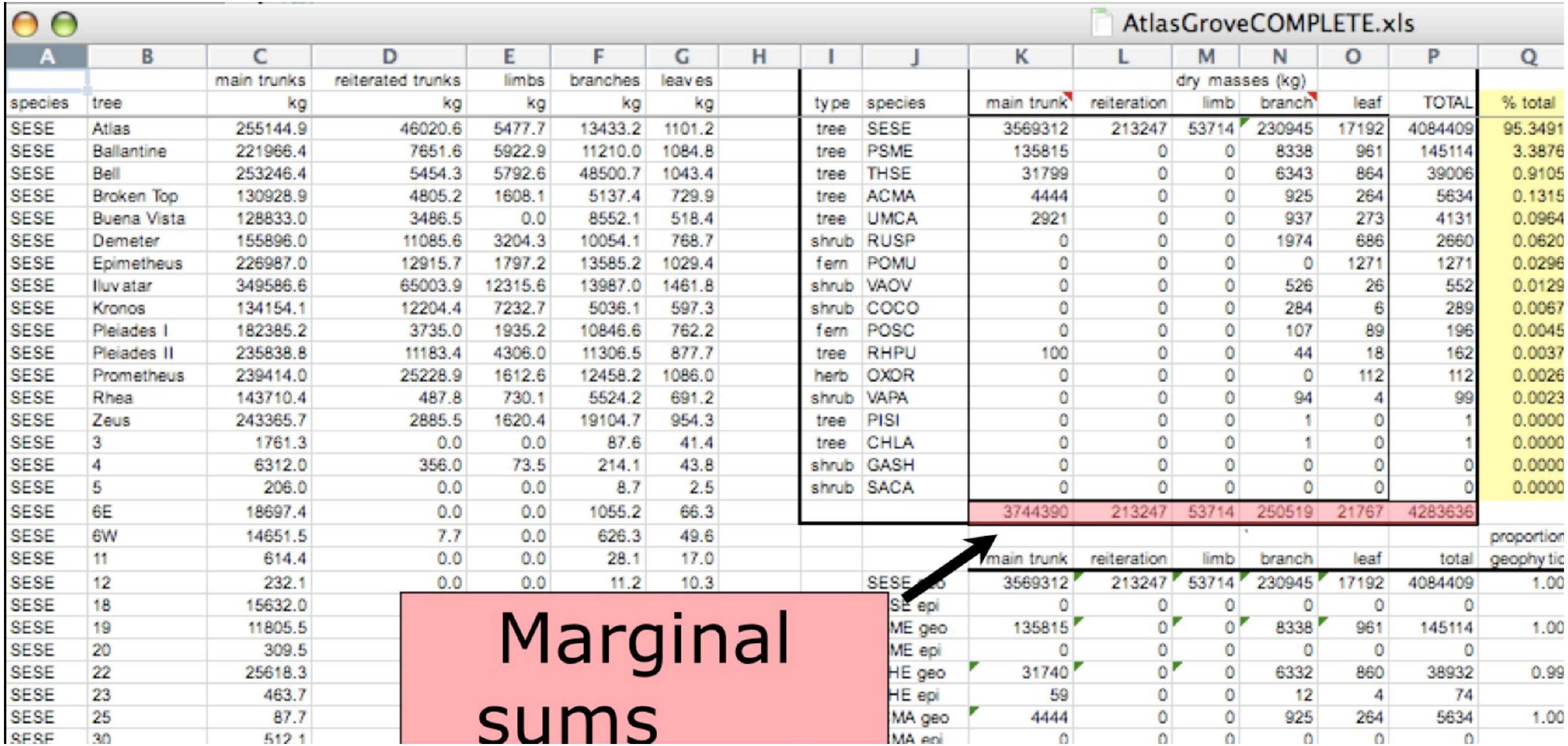
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		main trunks	reiterated trunks	limbs	branches	leaves						dry masses (kg)				
species	tree	kg	kg	kg	kg	kg		type	species	main trunk	reiteration	limb	branch	leaf	TOTAL	% total
SESE	Atlas	255144.9	46020.6	5477.7	13433.2	1101.2		tree	SESE	3569312	213247	53714	230945	17192	4084409	95.3491
SESE	Ballantine	221966.4	7651.6	5922.9	11210.0	1084.8		tree	PSME	135815	0	0	8338	961	145114	3.3876
SESE	Bell	253246.4	5454.3	5792.6	48500.7	1043.4		tree	THSE	31799	0	0	6343	864	39006	0.9105
SESE	Broken Top	130928.9	4805.2	1608.1	5137.4	729.9		tree	ACMA	4444	0	0	925	264	5634	0.1315
SESE	Buena Vista	128833.0	3486.5	0.0	8552.1	518.4		tree	UMCA	2921	0	0	937	273	4131	0.0964
SESE	Demeter	155896.0	11085.6	3204.3	10054.1	768.7		shrub	RUSP	0	0	0	1974	686	2660	0.0620
SESE	Epimetheus	226987.0	12915.7	1797.2	13585.2	1029.4		fern	POMU	0	0	0	0	1271	1271	0.0296
SESE	Iluvatar	349586.6	65003.9	12315.6	13987.0	1461.8		shrub	VAOV	0	0	0	526	26	552	0.0129
SESE	Kronos	134154.1	12204.4	7232.7	5036						0	0	284	6	289	0.0067
SESE	Pleiades I	182385.2	3735.0	1935.2	10846						0	0	107	89	196	0.0045
SESE	Pleiades II	235838.8	11183.4	4306.0	11306						0	0	44	18	162	0.0037
SESE	Prometheus	239414.0	25228.9	1612.6	12458						0	0	0	112	112	0.0026
SESE	Rhea	143710.4	487.8	730.1	5524						0	0	94	4	99	0.0023
SESE	Zeus	243365.7	2885.5	1620.4	19104						0	0	1	0	1	0.0000
SESE	3	1761.3	0.0	0.0	87						0	0	1	0	1	0.0000
SESE	4	6312.0	356.0	73.5	214						0	0	0	0	0	0.0000
SESE	5	206.0	0.0	0.0	8						0	0	0	0	0	0.0000
SESE	6E	18697.4	0.0	0.0	1055						213247	53714	250519	21767	4283636	
SESE	6W	14651.5	7.7	0.0	626											proportion
SESE	11	614.4	0.0	0.0	28						eration	limb	branch	leaf	total	geophytic
SESE	12	232.1	0.0	0.0	11.2	10.3			SESE geo	3569312	213247	53714	230945	17192	4084409	1.00
SESE	18	15632.0	0.0	0.0	946.3	106.8			SESE epi	0	0	0	0	0	0	
SESE	19	11805.5	0.0	0.0	770.1	80.3			PSME geo	135815	0	0	8338	961	145114	1.00
SESE	20	309.5	0.0	0.0	12.5	5.9			PSME epi	0	0	0	0	0	0	
SESE	22	25618.3	0.0	0.0	1504.0	120.2			TSHE geo	31740	0	0	6332	860	38932	0.99
SESE	23	463.7	0.0	0.0	18.9	4.5			TSHE epi	59	0	0	12	4	74	
SESE	25	87.7	0.0	0.0	4.1	1.3			ACMA geo	4444	0	0	925	264	5634	1.00
SESE	30	512.1	1.8	0.0	18.7	8.7			ACMA epi	0	0	0	0	0	0	

All the same variable?
No.

INSTEAD: all values in a column should be of the same type (tip: compare units)

Recognizing “untidy” data - marginal sums & stats

Marginal sums & statistics are combinations of observations



AtlasGroveCOMPLETE.xls

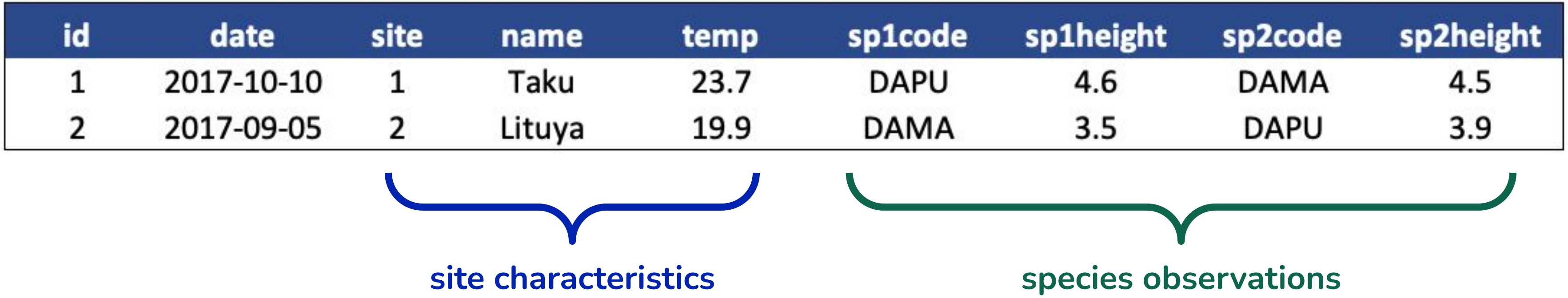
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		main trunks	reiterated trunks	limbs	branches	leaves						dry masses (kg)				
species	tree	kg	kg	kg	kg	kg		type	species	main trunk	reiteration	limb	branch	leaf	TOTAL	% total
SESE	Atlas	255144.9	46020.6	5477.7	13433.2	1101.2		tree	SESE	3569312	213247	53714	230945	17192	4084409	95.3491
SESE	Ballantine	221966.4	7651.6	5922.9	11210.0	1084.8		tree	PSME	135815	0	0	8338	961	145114	3.3876
SESE	Bell	253246.4	5454.3	5792.6	48500.7	1043.4		tree	THSE	31799	0	0	6343	864	39006	0.9105
SESE	Broken Top	130928.9	4805.2	1608.1	5137.4	729.9		tree	ACMA	4444	0	0	925	264	5634	0.1315
SESE	Buena Vista	128833.0	3486.5	0.0	8552.1	518.4		tree	UMCA	2921	0	0	937	273	4131	0.0964
SESE	Demeter	155896.0	11085.6	3204.3	10054.1	768.7		shrub	RUSP	0	0	0	1974	686	2660	0.0620
SESE	Epimetheus	226987.0	12915.7	1797.2	13585.2	1029.4		fern	POMU	0	0	0	0	1271	1271	0.0296
SESE	Iluv atar	349586.6	65003.9	12315.6	13987.0	1461.8		shrub	VAOV	0	0	0	526	26	552	0.0129
SESE	Kronos	134154.1	12204.4	7232.7	5036.1	597.3		shrub	COCO	0	0	0	284	6	289	0.0067
SESE	Pleiades I	182385.2	3735.0	1935.2	10846.6	762.2		fern	POSC	0	0	0	107	89	196	0.0045
SESE	Pleiades II	235838.8	11183.4	4306.0	11306.5	877.7		tree	RHPU	100	0	0	44	18	162	0.0037
SESE	Prometheus	239414.0	25228.9	1612.6	12458.2	1086.0		herb	OXOR	0	0	0	0	112	112	0.0026
SESE	Rhea	143710.4	487.8	730.1	5524.2	691.2		shrub	VAPA	0	0	0	94	4	99	0.0023
SESE	Zeus	243365.7	2885.5	1620.4	19104.7	954.3		tree	PISI	0	0	0	1	0	1	0.0000
SESE	3	1761.3	0.0	0.0	87.6	41.4		tree	CHLA	0	0	0	1	0	1	0.0000
SESE	4	6312.0	356.0	73.5	214.1	43.8		shrub	GASH	0	0	0	0	0	0	0.0000
SESE	5	206.0	0.0	0.0	8.7	2.5		shrub	SACA	0	0	0	0	0	0	0.0000
SESE	6E	18697.4	0.0	0.0	1055.2	66.3				3744390	213247	53714	250519	21767	4283636	
SESE	6W	14651.5	7.7	0.0	626.3	49.6										proportion
SESE	11	614.4	0.0	0.0	28.1	17.0				main trunk	reiteration	limb	branch	leaf	total	geophy tic
SESE	12	232.1	0.0	0.0	11.2	10.3			SESE	3569312	213247	53714	230945	17192	4084409	1.00
SESE	18	15632.0							SE epi	0	0	0	0	0	0	
SESE	19	11805.5							ME geo	135815	0	0	8338	961	145114	1.00
SESE	20	309.5							ME epi	0	0	0	0	0	0	
SESE	22	25618.3							HE geo	31740	0	0	6332	860	38932	0.99
SESE	23	463.7							HE epi	59	0	0	12	4	74	
SESE	25	87.7							MA geo	4444	0	0	925	264	5634	1.00
SESE	30	512.1							MA epi	0	0	0	0	0	0	

Marginal sums

INSTEAD: only identifying or measured variables should exist here; use a scripted language to analyze data / calculate summary stats

Denormalized (untidy) data

Data are **denormalized** when observations about different entities are combined. For example, each row in the data table below has site characteristics & species observations:



id	date	site	name	temp	sp1code	sp1height	sp2code	sp2height
1	2017-10-10	1	Taku	23.7	DAPU	4.6	DAMA	4.5
2	2017-09-05	2	Lituya	19.9	DAMA	3.5	DAPU	3.9

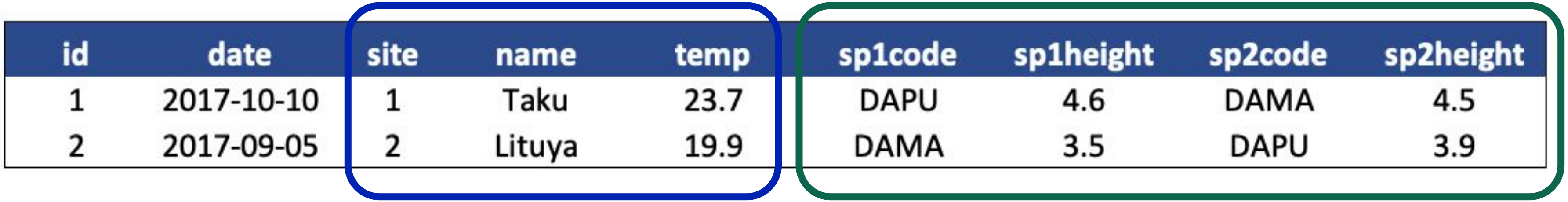
site characteristics

species observations

Importantly, a new species observation would require us to add columns (not a row) -- this data table organization is also known as **wide format**

Normalizing (tidying) this data table

To normalize this data table, we want to organize observations about each type of entity in it’s own table



id	date	site	name	temp	sp1code	sp1height	sp2code	sp2height
1	2017-10-10	1	Taku	23.7	DAPU	4.6	DAMA	4.5
2	2017-09-05	2	Lituya	19.9	DAMA	3.5	DAPU	3.9

Observed entities:

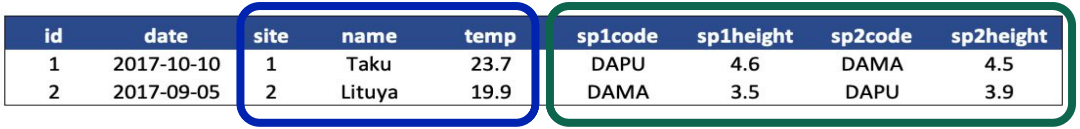
- site characteristics
- plant species

Variables associated with those observations:

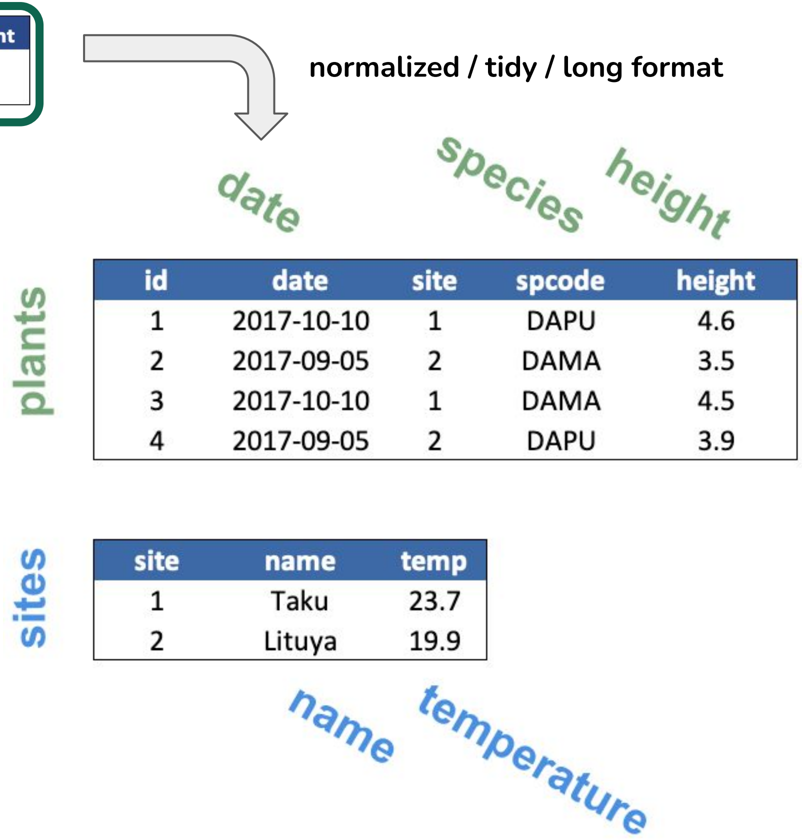
- temperature
- height

Normalized (tidy) data

denormalized / untidy / wide format



id	date	site	name	temp	sp1code	sp1height	sp2code	sp2height
1	2017-10-10	1	Taku	23.7	DAPU	4.6	DAMA	4.5
2	2017-09-05	2	Lituya	19.9	DAMA	3.5	DAPU	3.9



normalized / tidy / long format

id	date	site	spcode	height
1	2017-10-10	1	DAPU	4.6
2	2017-09-05	2	DAMA	3.5
3	2017-10-10	1	DAMA	4.5
4	2017-09-05	2	DAPU	3.9

site	name	temp
1	Taku	23.7
2	Lituya	19.9

We now have:

- Separate tables for each type of entity
- Each row represents a single observed entity
- Observations (rows) are all unique

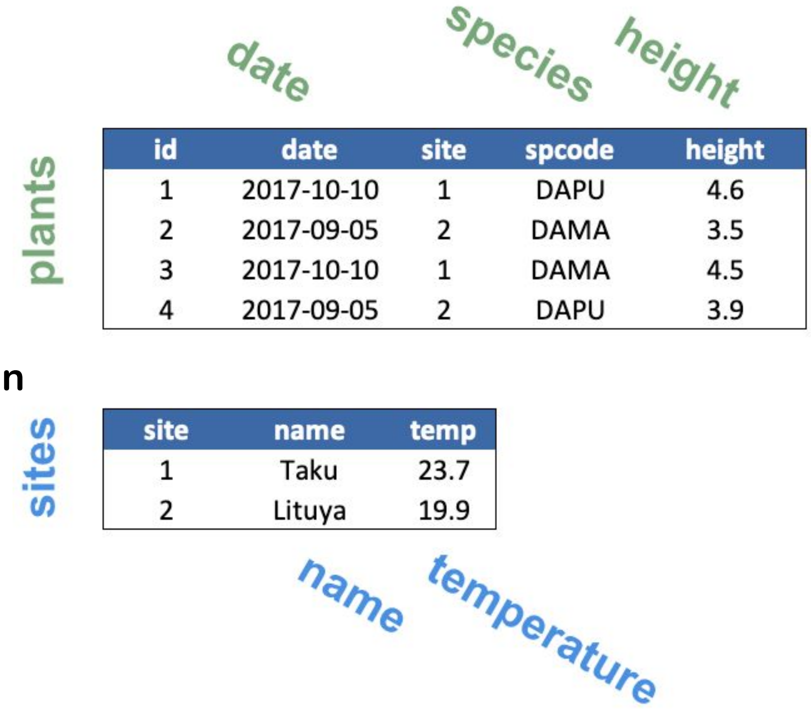
Additionally:

- All values in a column are of the same type
- All columns pertain to the same observed entity
- Each column represents either an identifying variable or a measured variable (no summary stats)

Normalized (tidy) data

Our normalized data now meet the guidelines set by Borer et al. 2009:

- Tables are designed to **add rows,** not columns
- Each **column** contains only **one type of information**
- A single piece of **data is recorded only once** & separated information collected at **different scales** into **different tables**

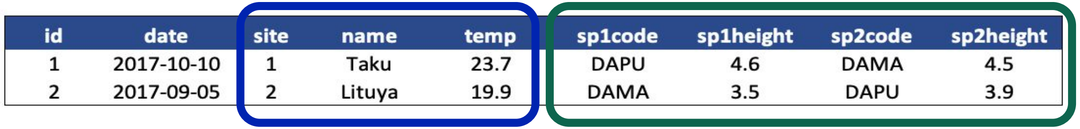

date
species
height
plants
sites
name
temperature

id	date	site	spcode	height
1	2017-10-10	1	DAPU	4.6
2	2017-09-05	2	DAMA	3.5
3	2017-10-10	1	DAMA	4.5
4	2017-09-05	2	DAPU	3.9

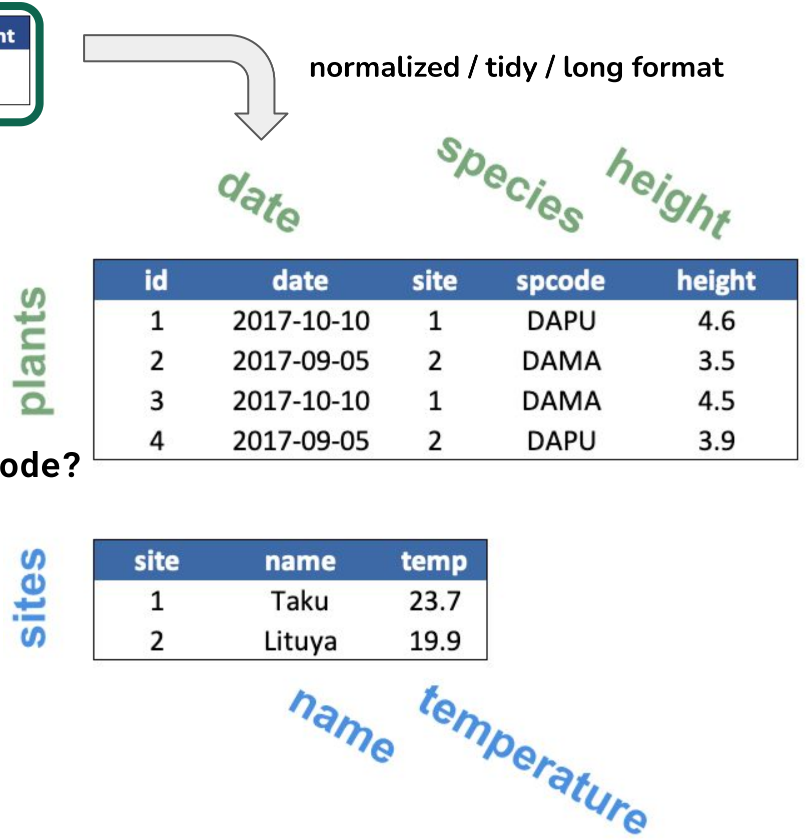
site	name	temp
1	Taku	23.7
2	Lituya	19.9

Normalized (tidy) data has lots of benefits!

denormalized / untidy / wide format



id	date	site	name	temp	sp1code	sp1height	sp2code	sp2height
1	2017-10-10	1	Taku	23.7	DAPU	4.6	DAMA	4.5
2	2017-09-05	2	Lituya	19.9	DAMA	3.5	DAPU	3.9



id	date	site	spcode	height
1	2017-10-10	1	DAPU	4.6
2	2017-09-05	2	DAMA	3.5
3	2017-10-10	1	DAMA	4.5
4	2017-09-05	2	DAPU	3.9

site	name	temp
1	Taku	23.7
2	Lituya	19.9

More easily filter rows for observations of interest

```
dplyr::filter(data = plant_data, spcode == “DAPU”)
```

Describe columns more precisely

`spcode` is the spp. identifier, but what exactly is `sp1code`, `sp2code`?

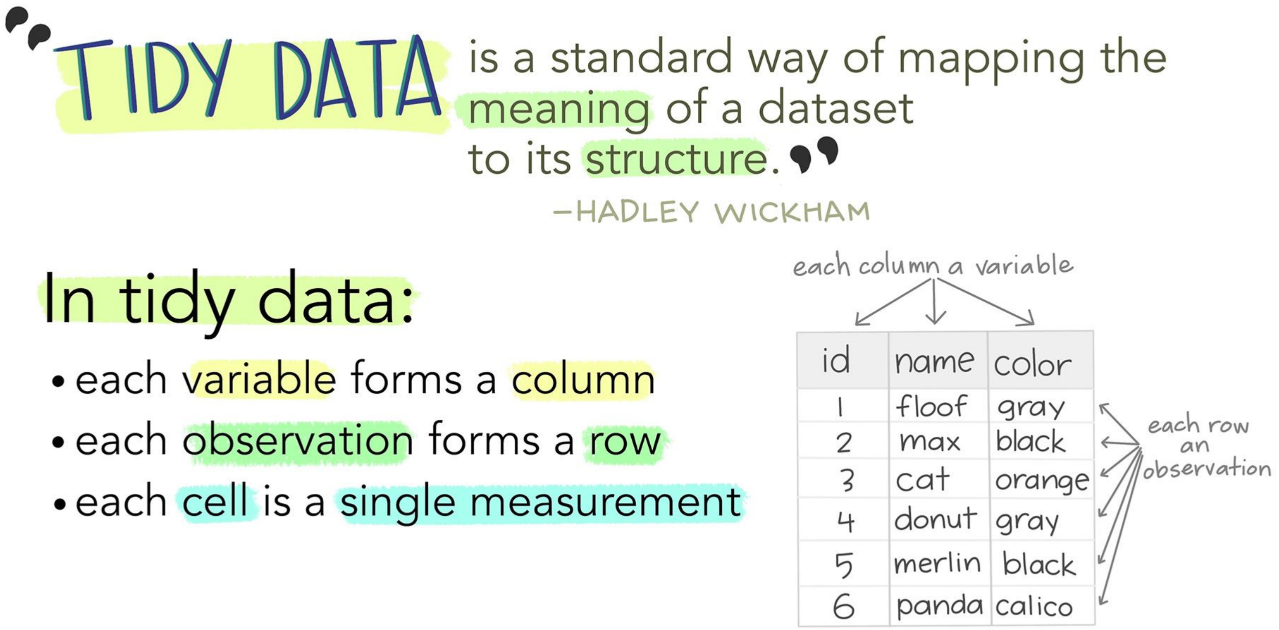
Optimize storage

not repeating data (e.g. date) reduces file size

Decrease errors from redundant updates

e.g. only need to update site name in table 2

One more look at tidy data



"TIDY DATA is a standard way of mapping the meaning of a dataset to its structure."

—HADLEY WICKHAM

In tidy data:

- each variable forms a column
- each observation forms a row
- each cell is a single measurement

id	name	color
1	floof	gray
2	max	black
3	cat	orange
4	donut	gray
5	merlin	black
6	panda	calico

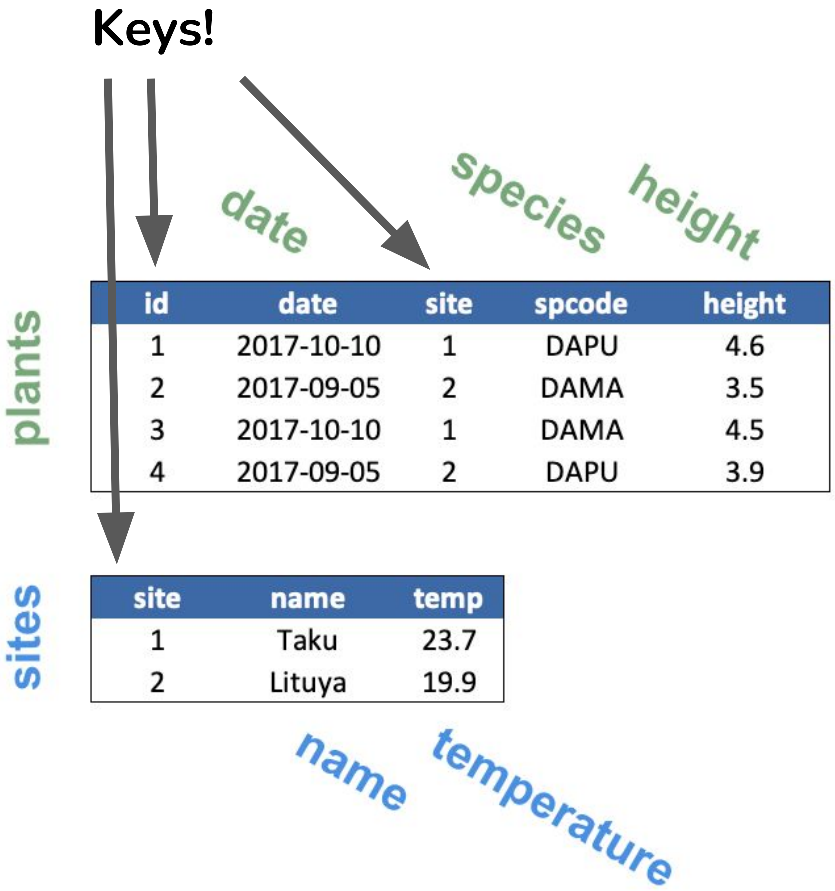
Wickham, H. (2014). Tidy Data. Journal of Statistical Software 59 (10). DOI: 10.18637/jss.v059.i10

artwork by @allison_horst

Using normalized data

Two tables?!? Don’t we want to analyze all these different measurements together??

(e.g. how will we use site temperature as a predictor variable for species composition?)



Keys!

date

species

height

plants

id	date	site	spcode	height
1	2017-10-10	1	DAPU	4.6
2	2017-09-05	2	DAMA	3.5
3	2017-10-10	1	DAMA	4.5
4	2017-09-05	2	DAPU	3.9

sites

site	name	temp
1	Taku	23.7
2	Lituya	19.9

name

temperature

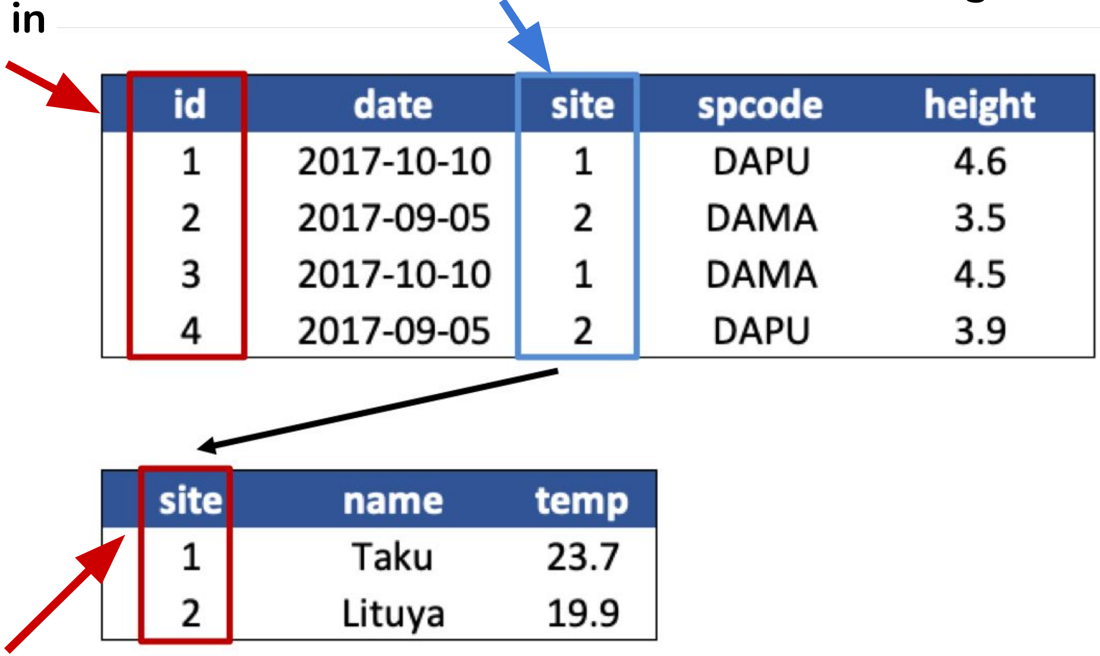
Keys allow us to link observations across tables

id uniquely identifies each row in the *plant* table

site references the primary key in the *site* table -- this is our linkage

Primary Key: a unique identifier for each observed entity, one per row

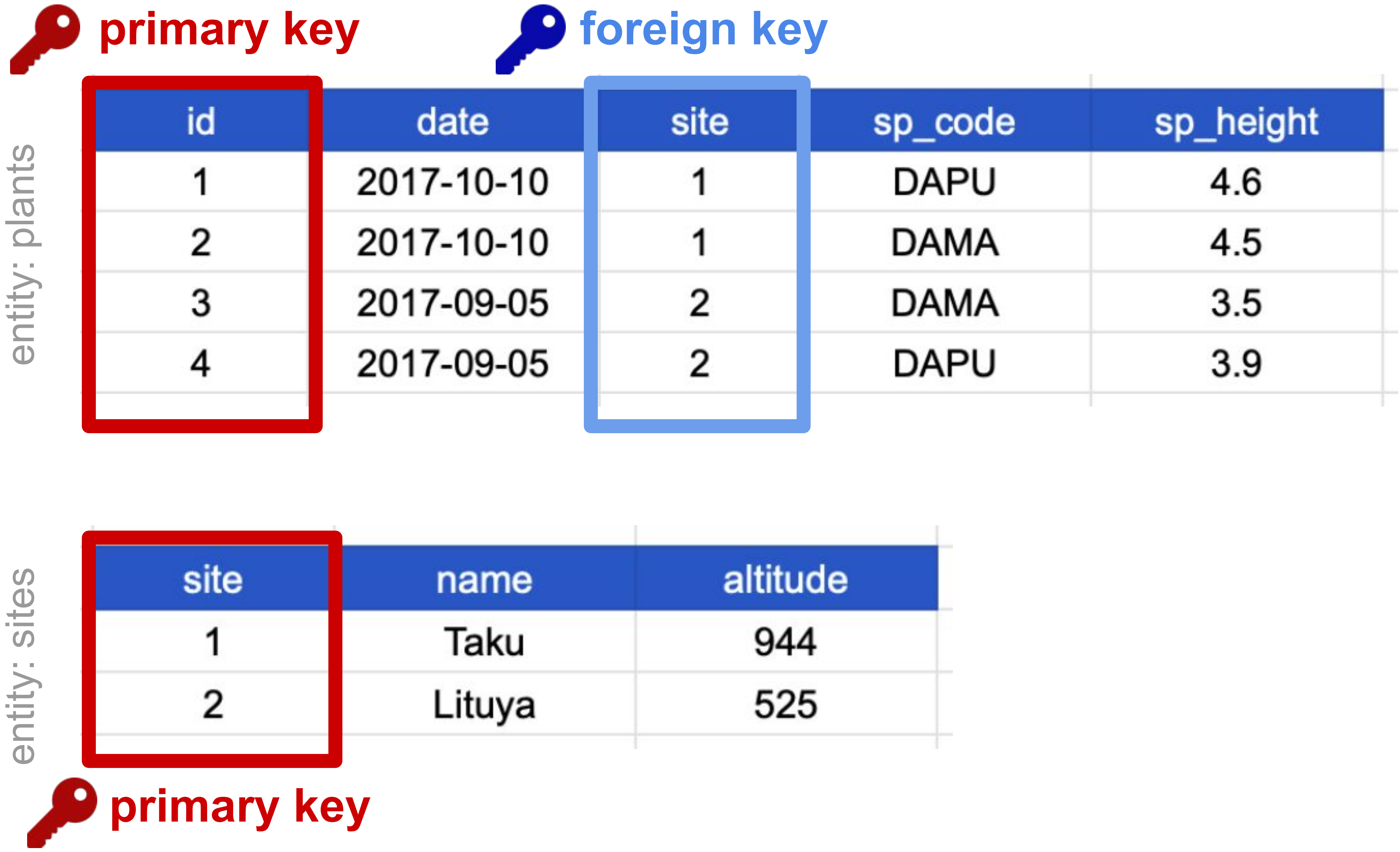
Foreign Key: reference to a primary key in another table (linkage)



id	date	site	spcode	height
1	2017-10-10	1	DAPU	4.6
2	2017-09-05	2	DAMA	3.5
3	2017-10-10	1	DAMA	4.5
4	2017-09-05	2	DAPU	3.9

site	name	temp
1	Taku	23.7
2	Lituya	19.9

site uniquely identifies each row in the *site* table



primary key

foreign key

entity: plants

id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

entity: sites

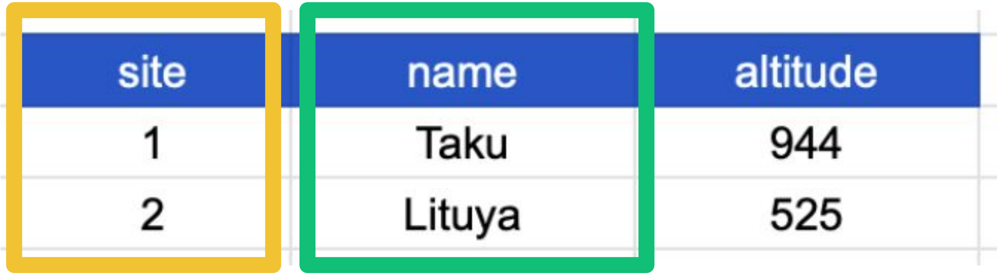
site	name	altitude
1	Taku	944
2	Lituya	525

primary key

surrogate key

natural key

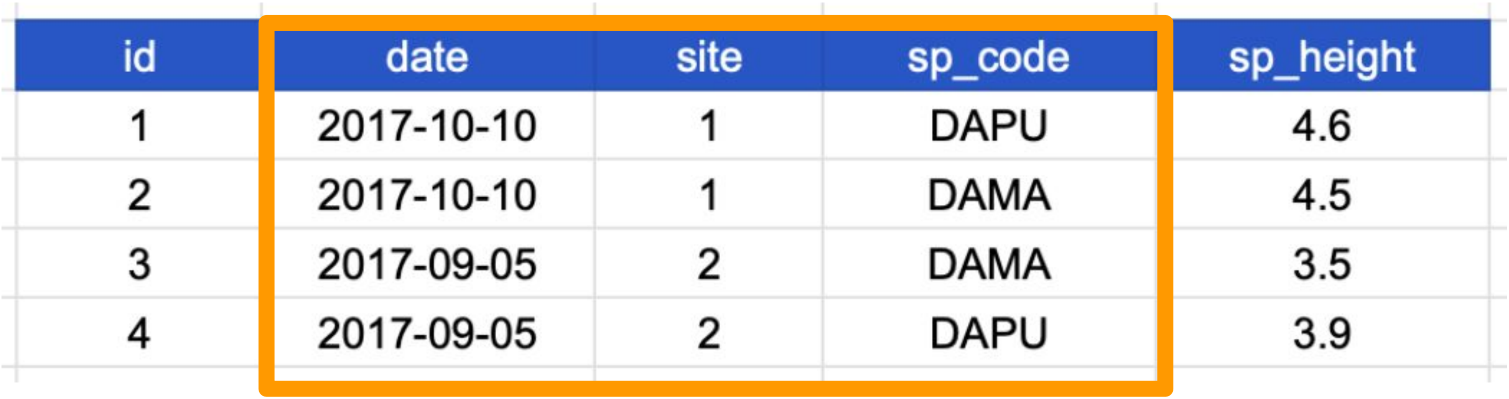
entity: sites



site	name	altitude
1	Taku	944
2	Lituya	525

entity: plants

compound key



id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

Keys allow us to link observations across tables

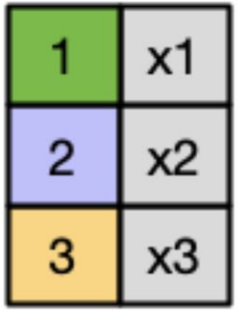
Joined the tables by **site**

id	date	site	spcode	height	name	temp
1	2017-10-10	1	DAPU	4.6	Taku	23.7
2	2017-09-05	2	DAMA	3.5	Lituya	19.9
3	2017-10-10	1	DAMA	4.5	Taku	23.7
4	2017-09-05	2	DAPU	3.9	Lituya	19.9

Merging data (aka “joins”)

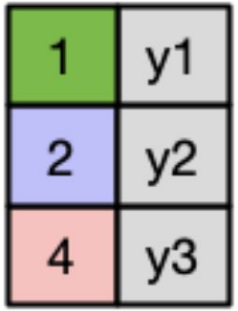
Merging (or joining) two related data tables based on key values is something you’ll probably do often during the data preparation (pre-analysis & visualization) stage. We’ll use these two tables to showcase how different types of joins work:

X



1	x1
2	x2
3	x3

Y



1	y1
2	y2
4	y3

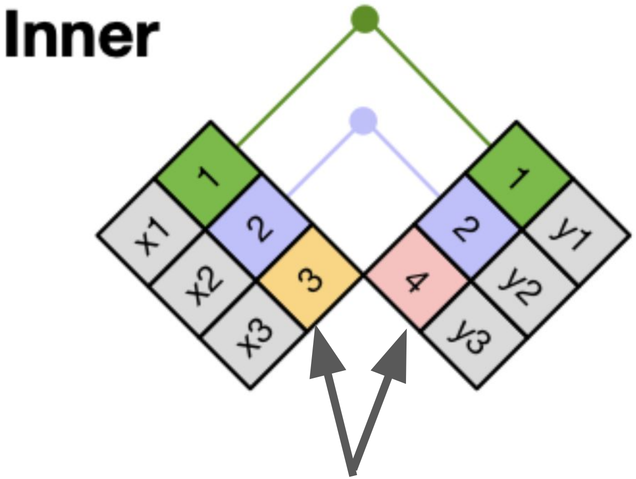
Inner join

X

1	x1
2	x2
3	x3

Y

1	y1
2	y2
4	y3



1	x1	y1
2	x2	y2

rows 3 (from left table) & 4 (from right table) are dropped because they have no matches

Merge (i.e. keep) the subset of rows that have matches in both the left and right tables

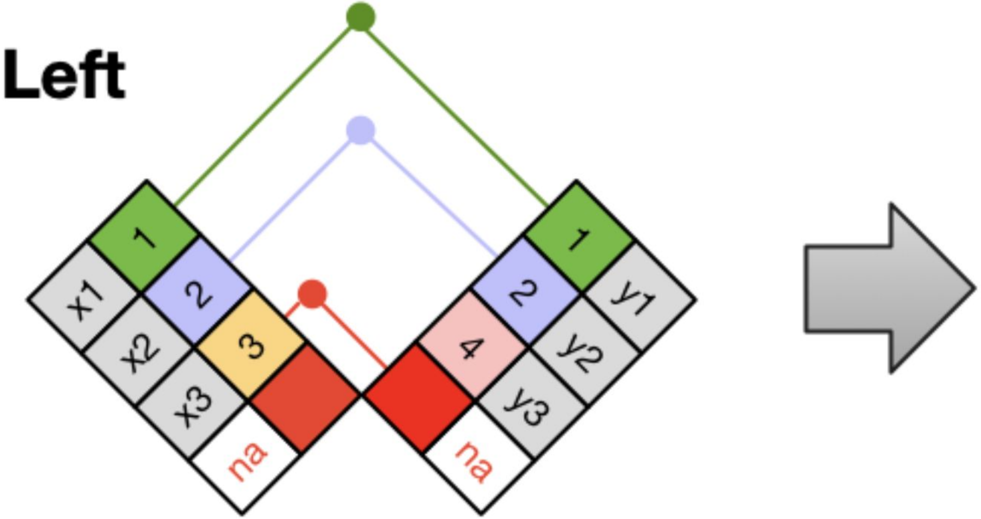
Left join

X

1	x1
2	x2
3	x3

Y

1	y1
2	y2
4	y3



1	x1	y1
2	x2	y2
3	x3	na

rows 1 & 2 (left table) have matches in the right table and are kept;
row 3 (left table) does not have a match in the right table, so it is kept and assigned an NA value

Take all rows from **left** table and merge on data from matching rows in right table

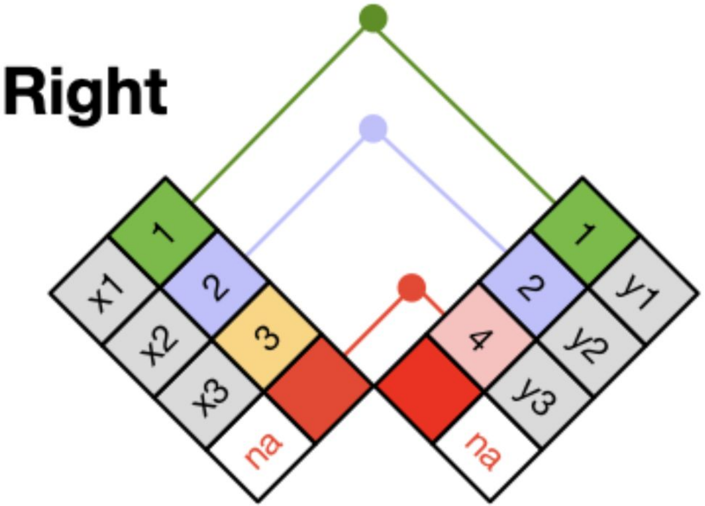
Right join

X

1	x1
2	x2
3	x3

Y

1	y1
2	y2
4	y3

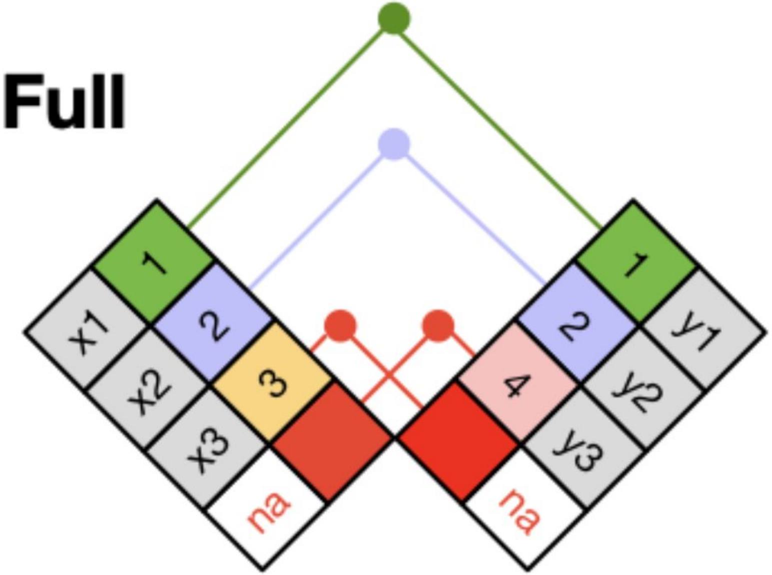


1	x1	y1
2	x2	y2
4	na	y3

rows 1 & 2 (right table) have matches in the left table and are kept;
row 4 (right table) does not have a match in the left table, so it is kept and assigned an NA value

Take all rows from **right** table and merge on data from matching rows in left table

Full join



X

1	x1
2	x2
3	x3

Y

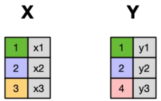
1	y1
2	y2
4	y3

1	x1	y1
2	x2	y2
3	x3	na
4	na	y3

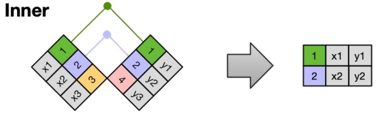
rows 1 & 2 are matched;
row 3 (left table) and row 4 (right table) are kept despite not having matches (assigned the value, NA)

Includes all rows from both tables and adds missing values (NAs) where necessary

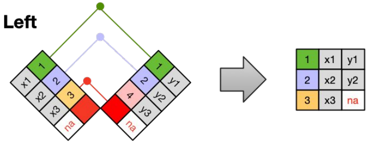
Spoiler: {dplyr} has super helpful functions for joining data



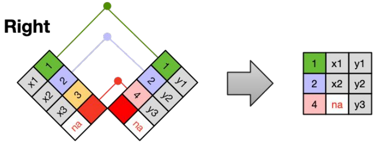
`inner_join(x, y)`



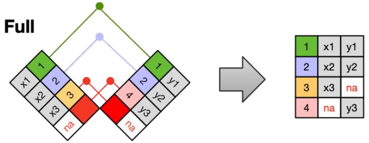
`left_join(x, y)`



`right_join(x, y)`



`full_join(x, y)`

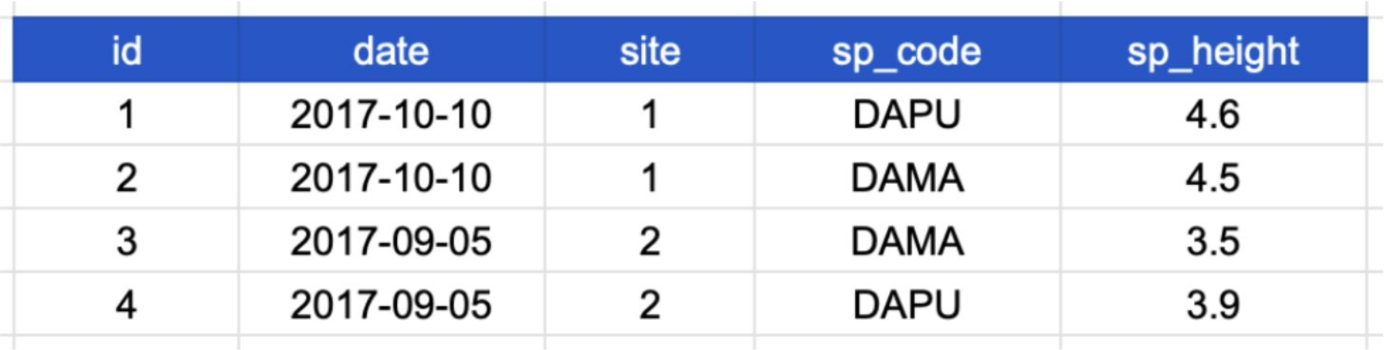


E-R Diagrams

- An Entity-Relationship model (E-R model), also known as an E-R diagram, is a way to draw a compact diagram that reflects the structure and relationships of the tables in a relational database.

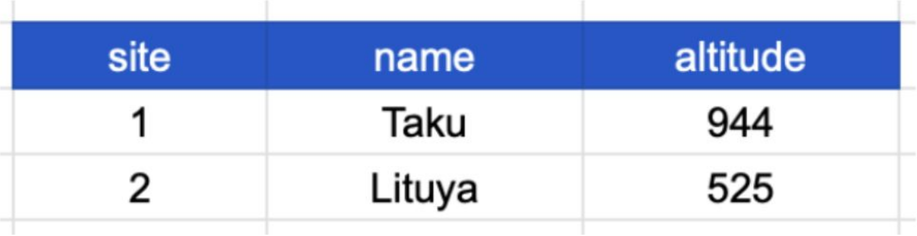
E-R Diagrams

1st entity: plants



id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

2nd entity: sites



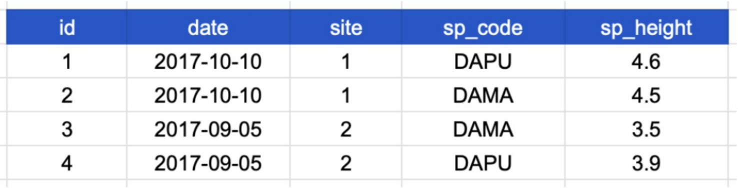
site	name	altitude
1	Taku	944
2	Lituya	525

Step 1: Identify Entities

plants

sites

1st entity: plants



id	date	site	sp_code	sp_height
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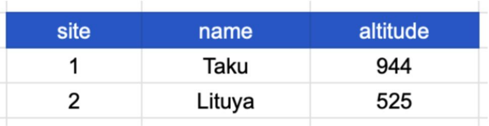
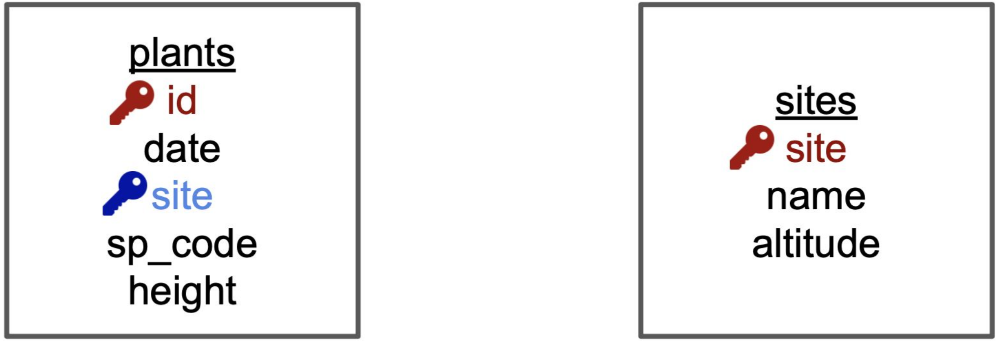
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

2nd entity: sites

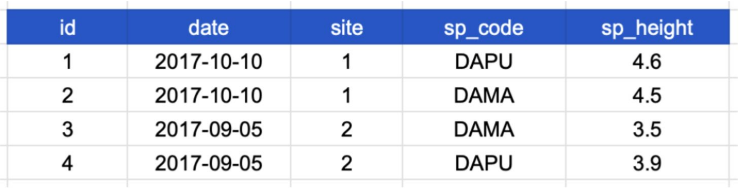


site	name	altitude
1	Taku	944
2	Lituya	525

Step 2: Add Variables/Keys

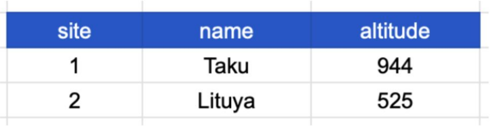


1st entity: plants



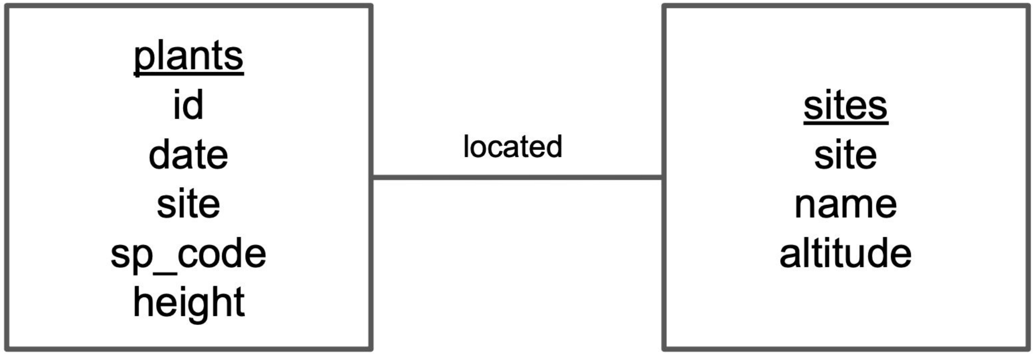
id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

2nd entity: sites



site	name	altitude
1	Taku	944
2	Lituya	525

Step 3: Add Relationships between Entities

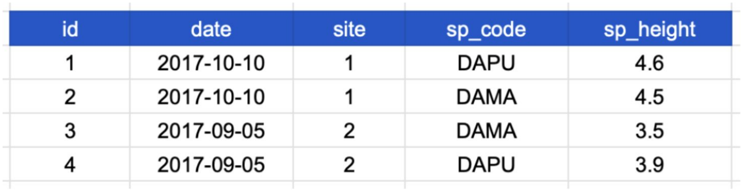


plants
id
date
site
sp_code
height

located

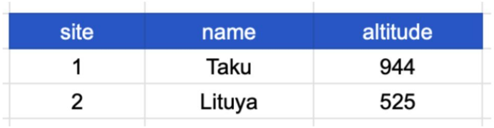
sites
site
name
altitude

1st entity: plants



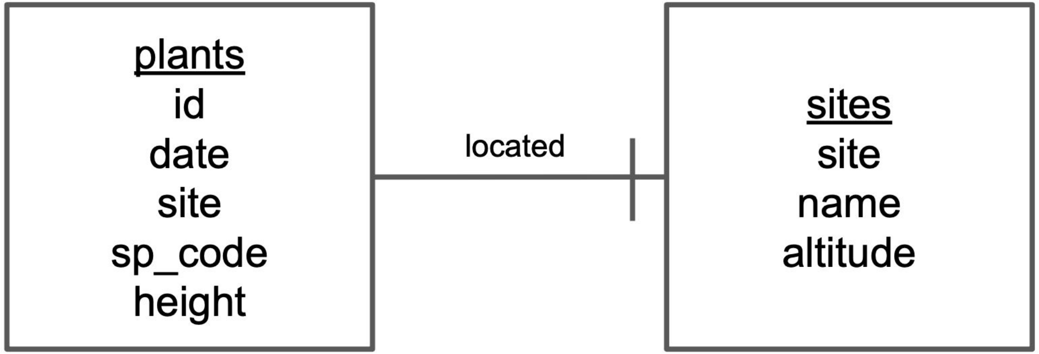
id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

2nd entity: sites



site	name	altitude
1	Taku	944
2	Lituya	525

Step 4: Add Cardinality

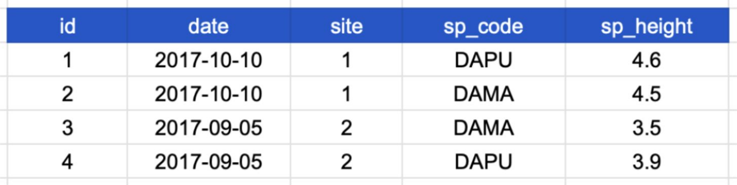


plants
id
date
site
sp_code
height

located

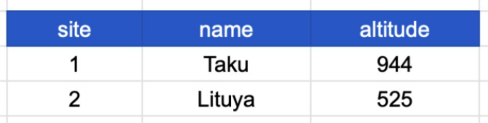
sites
site
name
altitude

1st entity: plants



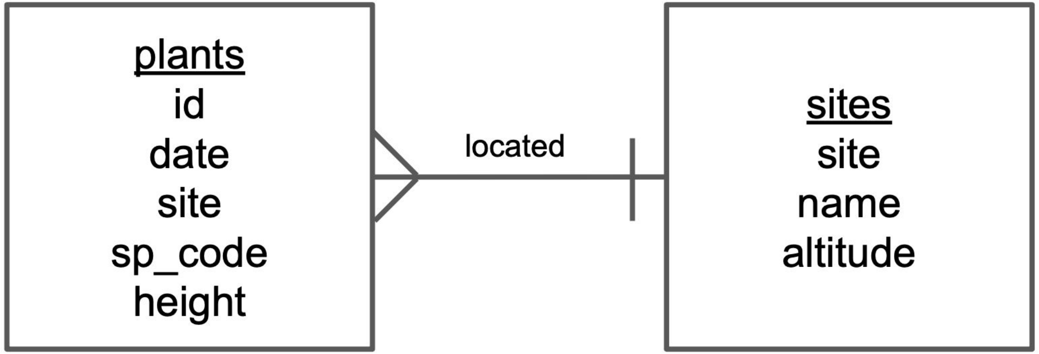
id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

2nd entity: sites



site	name	altitude
1	Taku	944
2	Lituya	525

Step 4: Add Cardinality

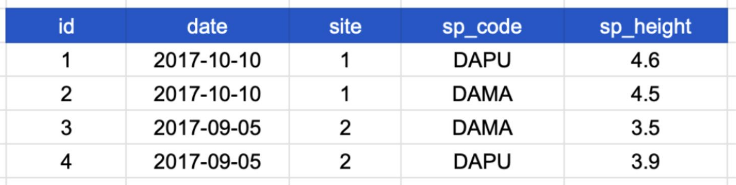


plants
id
date
site
sp_code
height

located

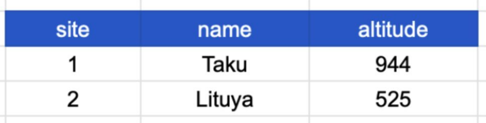
sites
site
name
altitude

1st entity: plants



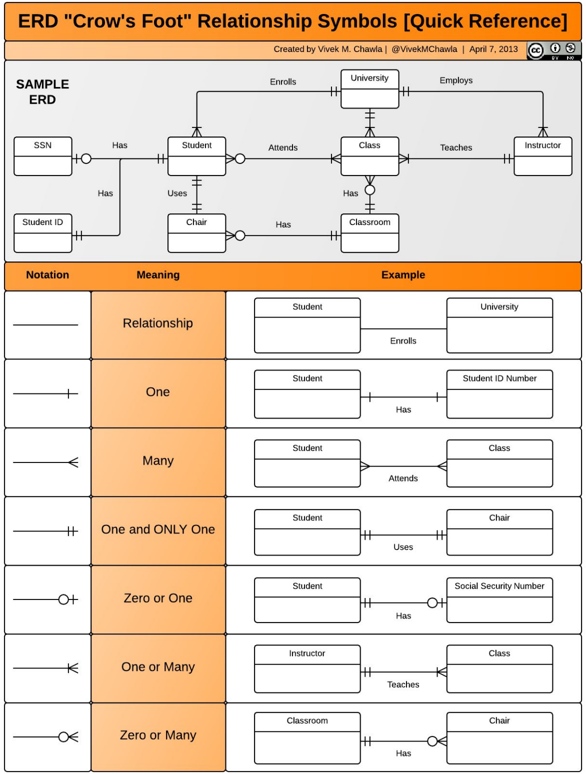
id	date	site	sp_code	sp_height
1	2017-10-10	1	DAPU	4.6
2	2017-10-10	1	DAMA	4.5
3	2017-09-05	2	DAMA	3.5
4	2017-09-05	2	DAPU	3.9

2nd entity: sites



site	name	altitude
1	Taku	944
2	Lituya	525

Step 4: Add Cardinality



ERD "Crow's Foot" Relationship Symbols [Quick Reference]

Created by Vivek M. Chawla | @VivekMChawla | April 7, 2013

SAMPLE ERD

Notation	Meaning	Example
——	Relationship	Student —— Enrolls —— University
——|	One	Student |—— Has ——| Student ID Number
——<	Many	Student >—— Attends ——< Class
——||	One and ONLY One	Student ||—— Uses ——|| Chair
——○|	Zero or One	Student ||—— Has ——○| Social Security Number
——|<	One or Many	Instructor ||—— Teaches ——|< Class
——○<	Zero or Many	Classroom ||—— Has ——○< Chair

Activity