Working With Tables

CMPU 101 – Problem Solving and Abstraction

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If we skipped over conditional expressions…

- Then, please read chapter 6
  - Or review the lab from Friday
  - And, check the next slide…

If/else expressions

To form an `if` expression:

```
if ⟨expression⟩:
   ⟨expression⟩
else:
   ⟨expression⟩
end
```

True–false question

True (“then”) answer

False (“else”) answer

Moving on to… Data Types

- Here are some data that can be represented with what we've seen so far:
  - A picture of a dog *Image*
  - The population of Azerbaijan *Number*
  - The complete text of the *Baghavad Gita* *String*
  - Whether or not I ate breakfast this morning *Boolean*

A more complex example

- What if we wanted to write a program to look up the population of any town in New York?
  - We can consider the last two census years – 2010 and 2020.
  - Next slide has a way to get us started…

The Population Function (plain text)

```
fun population(municipality :: String, year :: Number) -> Number:
  doc: "Return population of the municipality for the given year"
  if municipality == "New York":
    if year == 2010:
      8175133
    else if year == 2020:
      8804190
    else:
      raise("Bad year")
    end
  else if municipality == "Poughkeepsie":
    if year == 2010:
      43341
    else if year == 2020:
      45471
    else:
      raise("Bad year")
    end
  else:
    raise("Bad municipality")
  end
end
```

Data from: Local Government 2020 Census Interactive Dashboard
wwe1.osc.state.ny.us/localgov/2020-census-interactive-dashboard.htm

The Population Function (pyret)

View File Insert

```
1  use context essentials2021
2  fun population(municipality :: String, year :: Number) -> Number:
3    doc: "Return population of the municipality for the given year"
4    if municipality == "New York":
5      if year == 2010:
6        8175133
7      else if year == 2020:
8        8804190
9      else:
10       raise("Bad year")
11     end
12   else if municipality == "Poughkeepsie":
13     if year == 2010:
14       43341
15     else if year == 2020:
16       45471
17     else:
18       raise("Bad year")
19     end
20   else:
21     raise("Bad municipality")
22   end
23 end
24
```

The Population Function (pyret – nested if)

What's all this then? (pyret: new lang. feature)

View File Insert

```
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2  fun population(municipality :: String, year :: Number) -> Number:
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```

What's all this then? (pyret: raise)

raise…

- stops Pyret from evaluating the program and displays an error message to the user.
- This is different than returning a value, which lets Pyret continue as normal. Our "population" function returns numbers, but if it can't return a number, it will display one of these error messages.
- This is convenient when dealing with unexpected inputs.
  - Implied "contract" between caller & callee is broken
  - Data is not always "pure!"

A more complex example revisited

- What if we wanted to write a program to look up the population of any town in New York?
  - The approach used is not the best approach
    - Not at all!
    - But why?
    - Let’s take another look at the code

The Population Function (pyret)

View File Insert

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The Population Function (pyret)

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```

We have New York City…

We have Poughkeepsie…

We have… none of the other 1528 municipalities!

How to consider functions

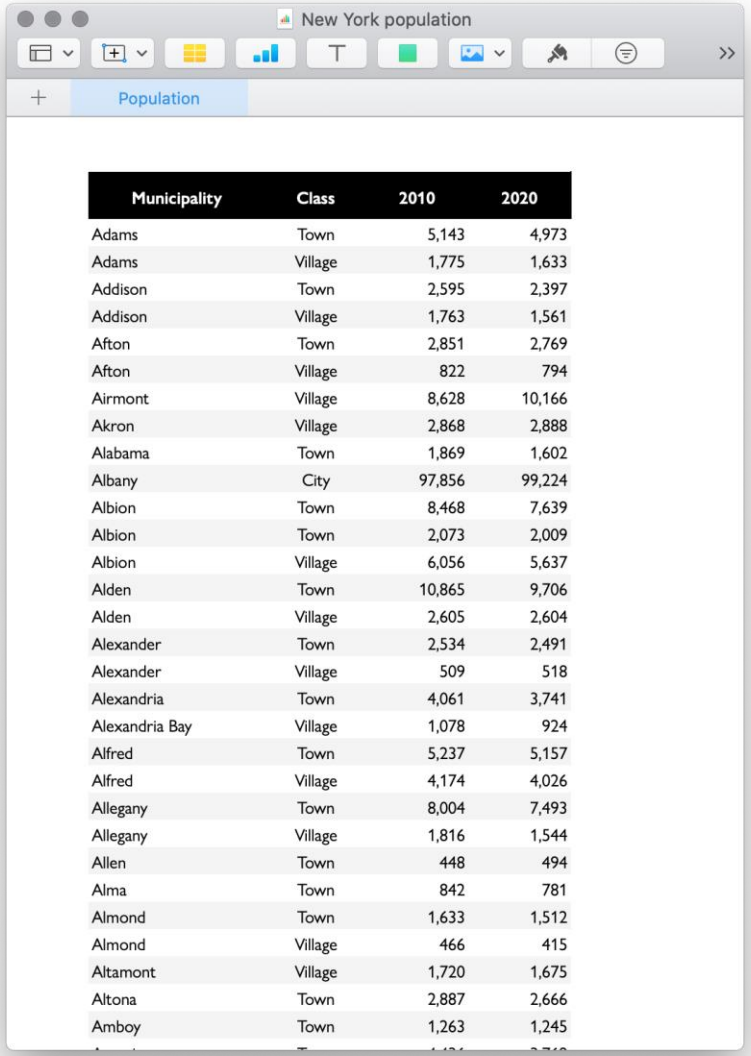
- KEY IDEA: Separate data from code computations.

  Then, we can reuse the data in as many functions as we want.
- Another KEY IDEA: Table-Driven Programming (my term!)

  i.e. Organize data into tables and we can tailor functions based on tables

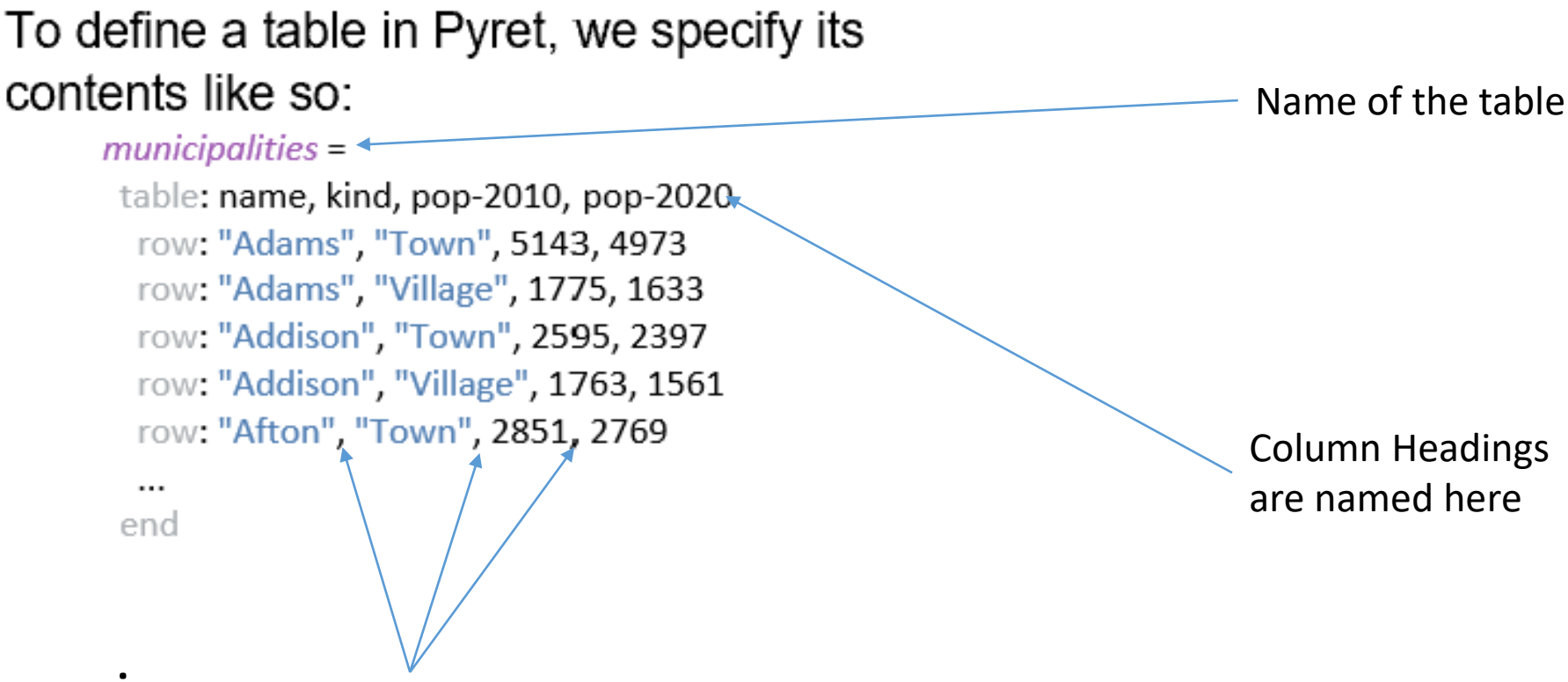
What's a Table?

- It is tabular data made up of rows/columns
  - similar to what you would see in a spreadsheet



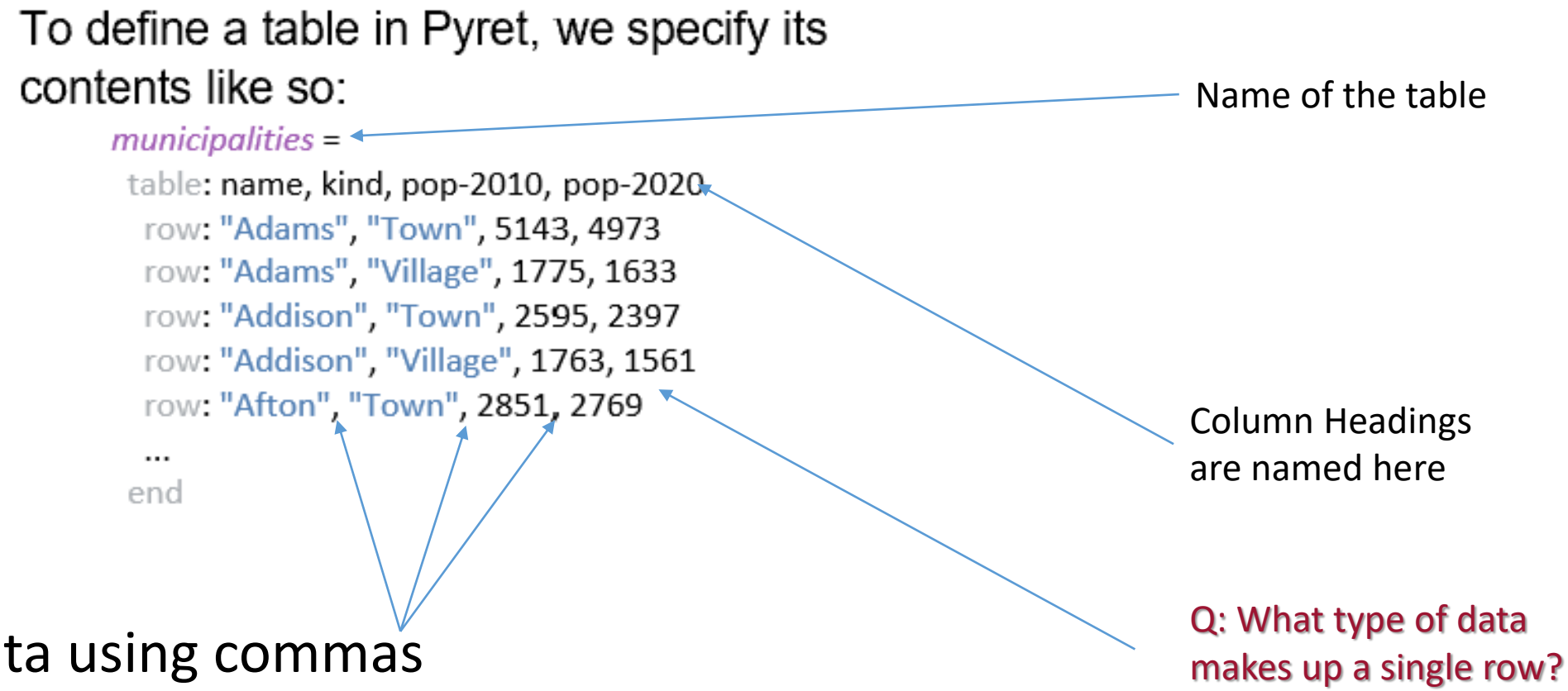
Municipality	Class	2010	2020
Adams	Town	5,143	4,973
Adams	Village	1,775	1,633
Addison	Town	2,595	2,397
Addison	Village	1,763	1,561
Afton	Town	2,851	2,769
Afton	Village	822	794
Airmont	Village	8,628	10,166
Akron	Village	2,868	2,888
Alabama	Town	1,869	1,602
Albany	City	97,856	99,224
Albion	Town	8,468	7,639
Albion	Town	2,073	2,009
Albion	Village	6,056	5,637
Alden	Town	10,865	9,706
Alden	Village	2,605	2,604
Alexander	Town	2,534	2,491
Alexander	Village	509	518
Alexandria	Town	4,061	3,741
Alexandria Bay	Village	1,078	924
Alfred	Town	5,237	5,157
Alfred	Village	4,174	4,026
Allegany	Town	8,004	7,493
Allegany	Village	1,816	1,544
Allen	Town	448	494
Alma	Town	842	781
Almond	Town	1,633	1,512
Almond	Village	466	415
Altamont	Village	1,720	1,675
Altona	Town	2,887	2,666
Amboy	Town	1,263	1,245

Defining a Table in pyret



- Dileneate data using commas

Defining a Table in pyret



- Dileneate data using commas

Defining a Table in pyret – adding data types

```
municipalities =
  table: name :: String, kind :: String,
    pop-2010 :: Number, pop-2020 :: Number
    row: "Adams", "Town", 5143, 4973
    row: "Adams", "Village", 1775, 1633
    row: "Addison", "Town", 2595, 2397
    row: "Addison", "Village", 1763, 1561
    row: "Afton", "Town", 2851, 2769
    #careful if you copy/paste from here,
    #all whitespace is not the same!
  end
```

Steps to Create the table

1. Name the table (minicipalities here) & click Run (“mi” and not “mu” here) -> table is created
2. Type in “minicipalities” & press enter key -> table is displayed
3. Good idea to simply include lines 2-7 in your programs, even if they aren’t necessary right now
4. (again) be careful when doing copy/paste, tab keys and space characters have different behavior

Publish or Perish

- So much data, so little time!
  - We can share tables using the “Publish” menu button rather than typing/copying/pasting/whatever
    - Important for sharing ginormous tables instead of gathering data yourself

Publish or Perish (2)

- End result is a sharable “link!”
  - That we can, umm, type/copy/paste/whatever.

Share or update the published copy

You can copy the link below to share the most recently published version with others.

```
://code.pyret.org/editor#share=1g2BPbORjYIbScjBvPi0fr7yKGMXb-9EB&v=6d122f0
```

You can copy the code below to use the published version as a library.

```
import shared-gdrive("minicipalities", "1g2BPbORjYIbScjBvPi0fr7yKGMXb-9EB"
```

You can also click Update below to copy the current version to the published version, or click Close to exit this window.

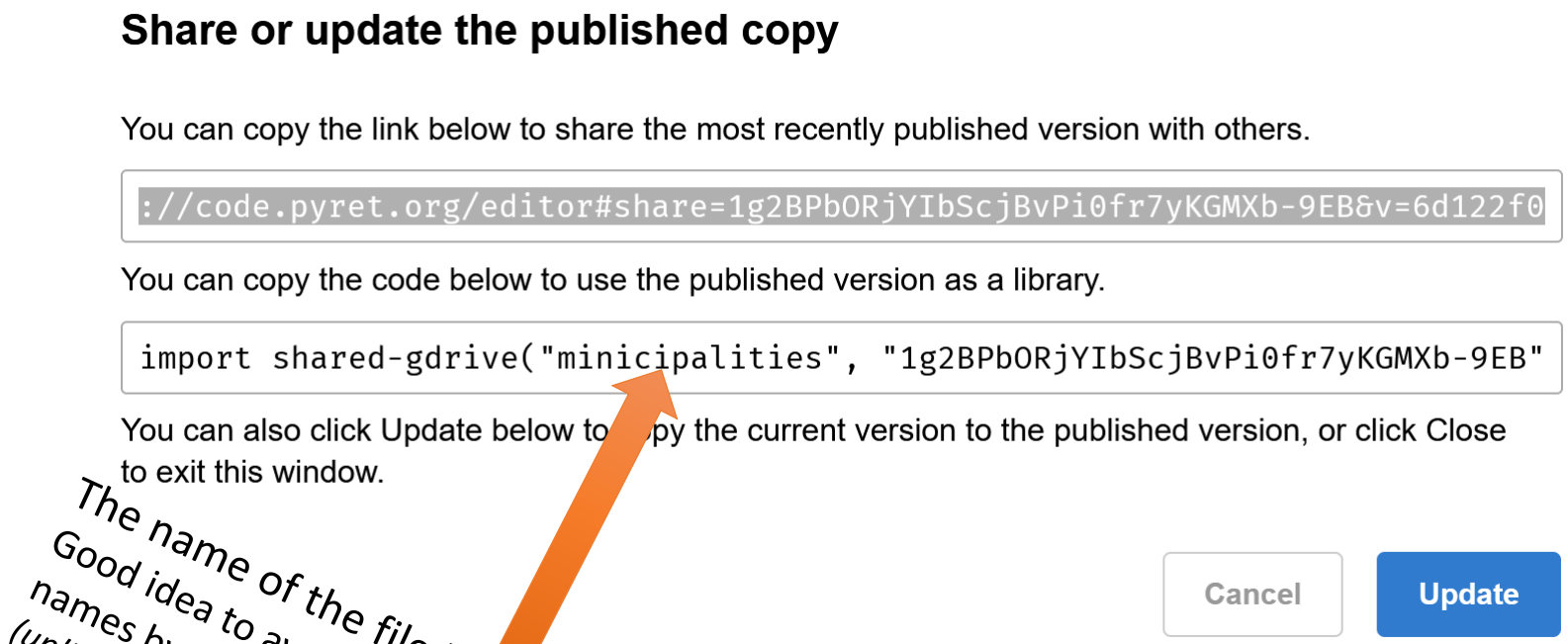
Cancel | Update

Publish or Perish (3)

- End result is a sharable “link!”
  - That we can, umm, type/copy/paste/whatever.

Publish or Perish (4)

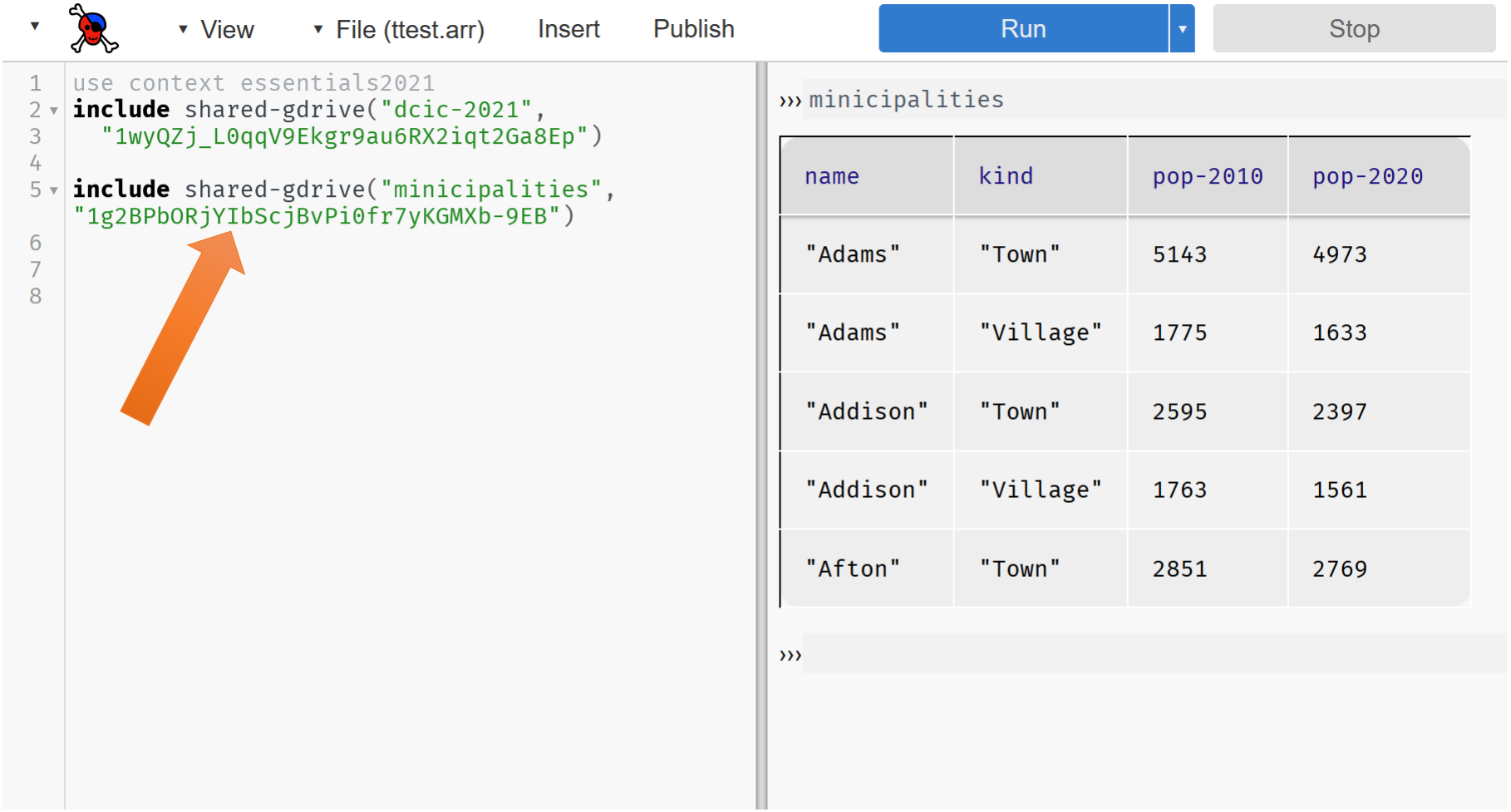
- End result is a sharable “link!”
  - That we can, umm, type/copy/paste/whatever.



The name of the file being shared is also used.
Good idea to avoid name collisions: create unique names by including (parts of) your name
(unlike what I did here!)

Publish or Perish (5)

- Here we use the table called minicipalities (as if we compiled the data ourselves)



Turning the Tables

- Let's use the complete set of data from the NY State website!

Turning the Tables (2)

- You should be able to copy/paste these lines into pyret to get the same results:
  - (It worked on my machine at home!)

```
# Load textbook functions for working with tables
include shared-gdrive("dcic-2021",
  "1wyQZj_L0qqV9Ekgr9au6RX2iqt2Ga8Ep")
# Load the full municipalities table
include shared-gdrive("municipalities",
"18eBAc9RcBfDQDpgjUkBQRj7LjgvAaXFs")

#Click "Run" then
#To see the tabular data in pyret,
#Type in "municipalities" sans quotes (the name of the table) on RHS
```

Ok, I've got a table. Now what?

- Now that we have the data in Pyret, we can write programs to "crunch the numbers" i.e. analyze the data!

- We'll need to learn some basic table manipulation functions first…

Extracting Rows

To get a row out of a table, specify its number, beginning with 0:

```
››› municipalities.row-n(0)
```

"name"	"Adams"	"kind"	"Town"	"pop-2010"	5143	"pop-2020"	4973

Row Data

- The data type returned by .row-n is a *Row*.
- We can access a value in the row by specifying the name of a column:
- ››› **municipalities.row-n(0)["name"]**
- "Adams"

- A note about the format of the above statement
  - The parentheses ( ) are saying that row-n is a function
  - The square brackets [ ] are saying to look up or extract the value of a particular column (the column named "name" here)

Row Data as input to a function

- We can write a function that takes a row as input:

```
fun population-decreased(r :: Row) -> Boolean:
  doc: "Return true if the municipality's population went down between 2010 and 2020"
  r["pop-2020"] < r["pop-2010"]
end
```

- If you remember Friday's lab, we can safely omit the explicit checks using *if* statements when returning a Boolean.

```
~~if r["pop-2020"] < r["pop-2010"]:~~
~~  true~~
~~else:~~
~~  false~~
~~end~~
```

Defining a Table in pyret – adding data types

```
municipalities =
  table: name :: String, kind :: String,
    pop-2010 :: Number, pop-2020 :: Number
    row: "Adams", "Town", 5143, 4973
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    #careful if you copy/paste from here,
    #all whitespace is not the same!
  end
```

Filtering data and (re)Ordering Tables

From this point on, we will need to include the textbook functions via:

```
# Load textbook functions for working with tables
include shared-gdrive("dcic-2021",  "1wyQZj_L0qqV9Ekgr9au6RX2iqt2Ga8Ep")
```

(I'll provide it with sample code; you'll just need to remember to copy/paste into your programs)

Filtering data and (re)Ordering Tables

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(I'll provide it with sample code; you'll just need to remember to copy/paste into your programs)

Filtering data and (re)Ordering Tables

Can we synthesize the data in municipalities to create a new table showing only cities where the population decreased between 2010 and 2020?

Filtering data and (re)Ordering Tables

Can we synthesize the data in municipalities to create a new table showing only cities where the population decreased between 2010 and 2020?

Spoiler Alert: YES, we can do that!

Brainstorming ways to do this: Table as parameter

```
# Create function that accepts a table and finds all municipalities with pop. decrease
fun filter-population-decreased(t :: Table) -> Table:
  if population-decreased(t.row-n(0)):
    ... # Keep row 0
    if population-decreased(t.row-n(1):
      ... # Keep row 1
    else:
      ... # Don't keep row 1
    end
  else:
    ... # Don't keep row 0
  end
end
```

Brainstorming ways to do this (2)

```
fun filter-population-decreased(t :: Table) -> Table:
  if population-decreased(t.row-n(0)):
    ... # Keep row 0
    if population-decreased(t.row-n(1):
      ... # Keep row 1
    else:
      ... # Don't keep row 1
    end
  else:
    ... # Don't keep row 0
  end
end
```

We would need 1500+ if statements? Noooooooo…
Good idea, but awful implementation. We don't really need to write code like this!
We can write general, all-purpose code to handle this.

This is the way…

filter-with can be used as a function to create a table with the desired set of rows…

```
filter-with(municipalities, population-decreased)
```

Two parameters

1. Our (municipalities) table
2. A *function* that filter-with uses. It will accept a row as a parameter and return a Boolean

- In other words, **filter-with** will iterate through the rows in our table, keeping what fits its criterion
  - A place with a decrease in population!

This is the way… more generally

filter-with(t :: Table, keep :: (Row -> Boolean)) -> Table

Read this as: Given a table and a predicate on rows, returns a table with only the rows for which the predicate returns true.

Again, two parameters

1. A data type of table
2. A keep *function* (the predicate) that filter-with uses. It will accept a row as a parameter and return a Boolean

A similar example with municipalities

We can also use **filter-with** to get a table made up of just the towns:

```
fun is-town(r :: Row) -> Boolean:
  doc: "Check if a row is for a town"
  r["kind"] == "Town"
end
filter-with(municipalities, is-town)
```

Expanding our options

We can also order the data by the values in one column:

order-by(municipalities, "pop-2020", false)

order-by(t :: Table, colname :: String, sort-up :: Boolean)
-> Table

Given a table and the name of a column in that table, return a table with the same rows but *ordered based on the named column*.

If **sort-up** is true, the table will be sorted in ascending order, otherwise (false) it will be in descending order.

We can combine all of these too!

How do we create a function that gives us the town with the smallest population?

?

We can combine all of these too!

How do we use the order-by function to give us the town with the smallest population?

```
order-by(
  filter-with(municipalities, is-town),
  "pop-2020",
  true).row-n(0)
```

Using what we have seen

- PROBLEM: We want to know the fastest-growing *towns* in New York.

Using what we have seen (2)

- PROBLEM: We want to know the fastest-growing *towns* in New York.
- i.e. we want a table containing only towns, sorted by the *percent change* in population.
- Let's break the problem statement into manageable parts

Using what we have seen (3)

- PROBLEM: We want to know the fastest-growing *towns* in New York.
- i.e. we want a table containing only towns, sorted by the *percent change* in population.
- Let's break the problem statement into manageable parts
  - Make a new table and…
  1. Filter out the cities, etc. (i.e. only towns)
  2. Calculate percentage change in population
  3. Build a (new) column for percentage change
  4. Sort the table based on that new column in *descending* order

Building a solution (1)

- PROBLEM: We want to know the fastest-growing *towns* in New York.
- i.e. we want a table containing only towns, sorted by the *percent change* in population.
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  - Make a new table and…
  1. Filter out the cities, etc. (i.e. only towns)
     - *towns* = filter-with(municipalities, is-town)
  2. Calculate percentage change in population
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Building a solution (2)

- PROBLEM: We want to know the fastest-growing *towns* in New York.
- i.e. we want a table containing only towns, sorted by the *percent change* in population.
- Let's break the problem statement into manageable parts
  - Make a new table and…
  1. Filter out the cities, etc. (i.e. only towns)
     - *towns* = filter-with(municipalities, is-town)
  2. Calculate percentage change in population

```
fun percent-change(r :: Row) -> Number:
  doc: "Compute the percentage change for the population of the given municipality between 2010 and 2020"
  (r["pop-2020"] - r["pop-2010"]) /  r["pop-2010"]
end
```

  3. Build a (new) column for percentage change
  4. Sort the table based on that new column in *descending* order

Building a solution (3)

- PROBLEM: We want to know the fastest-growing *towns* in New York.
- i.e. we want a table containing only towns, sorted by the *percent change* in population.
- Let's break the problem statement into manageable parts
  - Make a new table and…
  1. Filter out the cities, etc. (i.e. only towns)
     - *towns* = filter-with(municipalities, is-town)
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fun percent-change(r :: Row) -> Number:
  doc: "Compute the percentage change for the population of the given municipality between 2010 and 2020"
  (r["pop-2020"] - r["pop-2010"]) /  r["pop-2010"]
end
```

  3. Build a (new) column for percentage change

```
towns-with-percent-change =
  build-column(towns, "percent-change", percent-change)
```

  4. Sort the table based on that new column in *descending* order

Building a solution (4)

- PROBLEM: We want to know the fastest-growing *towns* in New York.
- i.e. we want a table containing only towns, sorted by the *percent change* in population.
- Let's break the problem statement into manageable parts
  - Make a new table and…
  1. Filter out the cities, etc. (i.e. only towns)
     - *towns* = filter-with(municipalities, is-town)
  2. Calculate percentage change in population

```
fun percent-change(r :: Row) -> Number:
  doc: "Compute the percentage change for the population of the given municipality between 2010 and 2020"
  (r["pop-2020"] - r["pop-2010"]) /  r["pop-2010"]
end
```

  3. Build a (new) column for percentage change

```
towns-with-percent-change =
  build-column(towns, "percent-change", percent-change)
```

  4. Sort the table based on that new column in *descending* order

```
fastest-growing-towns =
  order-by(towns-with-percent-change,
    "percent-change", false)
```

Full solution… almost (see how it runs!)

- PROBLEM: We want to know the fastest-growing *towns* in New York.

```
fun percent-change(r :: Row) -> Number:
  doc: "Compute the percentage change for the population of the given municipality between 2010 and 2020"
  (r["pop-2020"] - r["pop-2010"]) /
  r["pop-2010"]
end
Fun is-town(r :: Row) -> Boolean:
  doc: "Check if a row is for a town"
  r["kind"] == "Town"
end
towns = filter-with(municipalities, is-town)

towns-with-percent-change =
  build-column(towns, "percent-change", percent-change)

fastest-growing-towns =
  order-by(towns-with-percent-change,
    "percent-change", false)

fastest-growing-towns
```

Acknowledgements

- This lecture incorporates material from:
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- And, Jonathan Gordon