Old Methods…New Languages

- Why learn scripting methods for GIS/ spatial analysis?
  - Automate redundant or annoying analysis tasks
  - Batch geoprocessing or batch data collection
  - Simplify software interface or geoprocessing tools
  - Manipulate layers in a map
  - Create or modify existing geometries (point, line, polygon)
  - Add new tools or models to software

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Python Scripting

- Why Python?
  - It's free!
  - Established user community
  - Large library
  - Easy to understand syntax
  - Scalable and modular
  - Cross-platform integration (Windows, Unix, Linux, Mac)
  - Supports object-orientation
  - Many GIS tools and applications being built with Python or use Python as a gateway
  - http://www.data-analysis-in-python.org/t_gis.html

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Python Scripting

- Python used in applications outside of GIS/spatial analysis
  - Learning computer logic and enhancing development skills
  - Web, desktop, open source
- Most spatial analysis software integrates Python libraries in some way

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What Do You Want from Python?

- Geocoding?
- Geometric operations?
  - Distance measurement?
  - Do polygons intersect?
  - Does a point exist within a geographic boundary?
- Spatial statistics?
  - Spatial autocorrelation?
  - Spatial regression?
- Map creation/map display?

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Useful Spatial Analysis Libraries in Python

- Data Handling:
  - Shapely, GDAL/OGR, pyQGIS, pyshp, pyproj
- Analysis:
  - Shapely, numpy, scipy, pandas, GeoPandas, PySAL, Rasterio, scikit-learn, scikit-image
- Plotting:
  - matplotlib, prettyplotlib, descartes, cartopy
- https://github.com/SpatialPython/spatial_python/blob/master/packages.md

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Python Documentation

- Texts
  - Python Programming: An Introduction to Computer Science by John Zelle
  - Python Scripting for ArcGIS by Paul Zandbergen
  - Learning Geospatial Analysis with Python by Joel Lawhead
  - Modern Spatial Econometrics in Practice by Luc Anselin and Sergio Rey
  - The PyQGIS Programmers Guide by Gary Sherman
- Websites
  - http://www.python.org
  - GIS Q&A at StackExchange (http://gis.stackexchange.com)
  - http://resources.arcgis.com/en/communities/python/

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Python Documentation

- More references
  - "Dive into Python" (Chapters 2 to 4)
    - http://www.diveintopython.net/
  - Python 101 – Beginning Python
    - http://www.davekuhlman.org/python_book_01.pdf
  - Python Wiki
    - https://wiki.python.org/moin/BeginnersGuide/NonProgrammers
  - The Python Quick Reference
    - http://rgruet.free.fr/

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Python Versions

- Python 2.* or Python 3.*…which to choose?
  - Python 3 launched in ~2008 but was slow to be adopted
  - Ex. ArcGIS Desktop only uses Python 2.7 (ArcGIS Pro finally uses Python 3.*)
- Use Python 3 when available but Python 2.7 is still common and should not hinder your analysis

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What do I install? Where is it available?

- Open Source Geospatial Foundation (OSGeo) has some good places to begin
  - Windows? (https://trac.osgeo.org/osgeo4w/)
  - Mac? Linux? (http://live.osgeo.org/en/index.html)
- Install desktop software and/or Python libraries individually
- Public labs on campus https://gis.rcc.uchicago.edu/node/3 have some packages installed
- Check out RCC cluster https://rcc.uchicago.edu/docs/software/modulelist.html

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Python Translator

- Most users should have a basic knowledge of the software and its functions
  - The software must interpret your intent
  - Have a clear idea of your final product
- Users need a context to understand syntax
  - Ex. Communicate with someone speaking another language
- Jumping into spatial analysis is not as simple as it seems….

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Let's Measure Some Distances!

- **How far is Jackson, MS from Biloxi, MS?**

  measuredistances

- Ever heard of the Haversine formula?
- Know how to change projection/ coordinate systems?

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Geocoding Services and GIS Platforms:

RCC GIS

ArcGIS + ArcGIS Online
QGIS

GeoPandas (Shapely)

PySAL from GeoDa

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Python Interface

- Multiple ways to edit Python scripts
  - IDLE – a cross-platform Python development environment
  - Other Python editors: PyCharm, Notepad++, etc.
  - PythonWin – a Windows only interface to Python
  - Python Shell – running 'python' from the Command Line opens this interactive shell

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Getting Creative with Python

- Geocoding data for free
  - Python library named GEOCODER
  - Function uses Google Maps API to geocode locations
    - Google API only allows 2000 records per day per IP address and only 10 records per second
- Combine GEOCODER, CSV, and TIME library functions
  - Only send 10 requests at a time up to 2000

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Basic Spatial Functions with Python

- GeoPandas (http://geopandas.org) includes very useful tools for the novice user
  - Make maps, manage projections, manipulate geometry, geocoding, merging/aggregation
  - https://automating-gis-processes.github.io/2016/Lesson3-spatial-join.html

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Fun with Spatial Statistics

- PySAL allows for spatial stats methods to be implemented with ease
  - User must be familiar with how methods work first before jumping in
  - http://pysal.readthedocs.io/en/latest/users/tutorials/autocorrelation.html#moran-s-i
- Spatial weights, spatial autocorrelation, spatial econometrics, etc.
  - Output is no different than you would get in other GIS/spatial analysis software

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ArcGIS with Python tutorial

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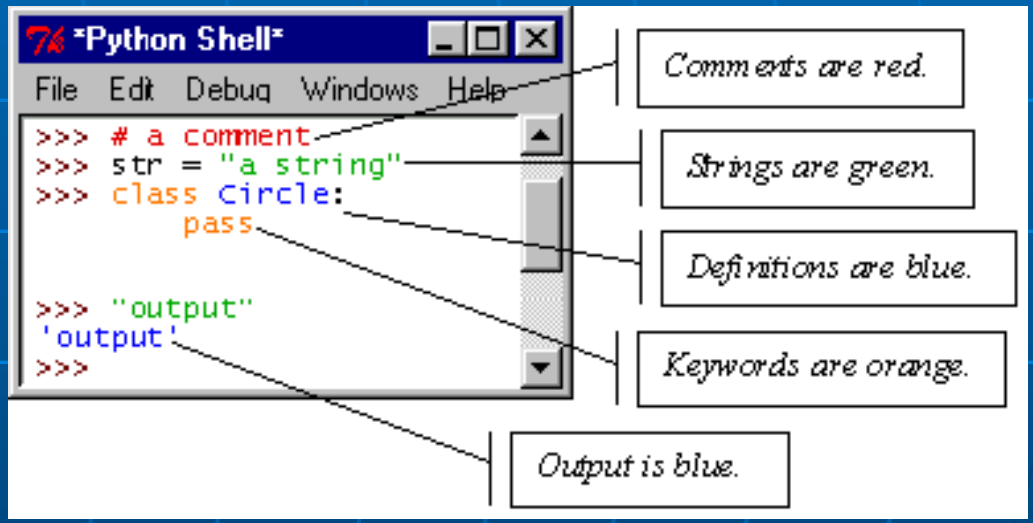
Python Interface

- Editors helps you program in Python by:
  - color-coding your program code
  - debugging
  - auto-indent
  - interactive shell



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Let's Measure Some Distances!

- In ArcGIS:

```
from osgeo import ogr, osr
driver = ogr.GetDriverByName('ESRI Shapefile')
dataSource = driver.Open(inputlayer, 0) #0 means read-only
layer = dataSource.GetLayer()
source = layer.GetSpatialRef()
target = osr.SpatialReference()
target.ImportFromEPSG(4326)
transform = osr.CoordinateTransformation(source, target)
return [doProjection(feature, transform) for feature in layer]
```

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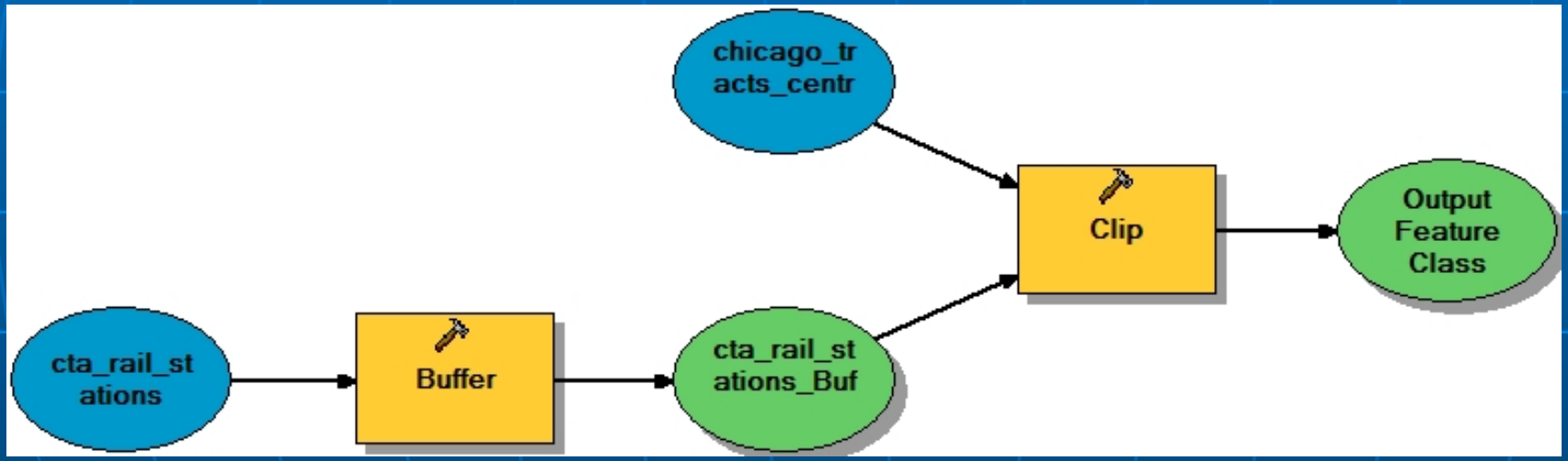
ArcGIS Modelbuilder

- ModelBuilder provides a flow diagram interface to start your task



- A majority of parameters can and should be set in ModelBuilder

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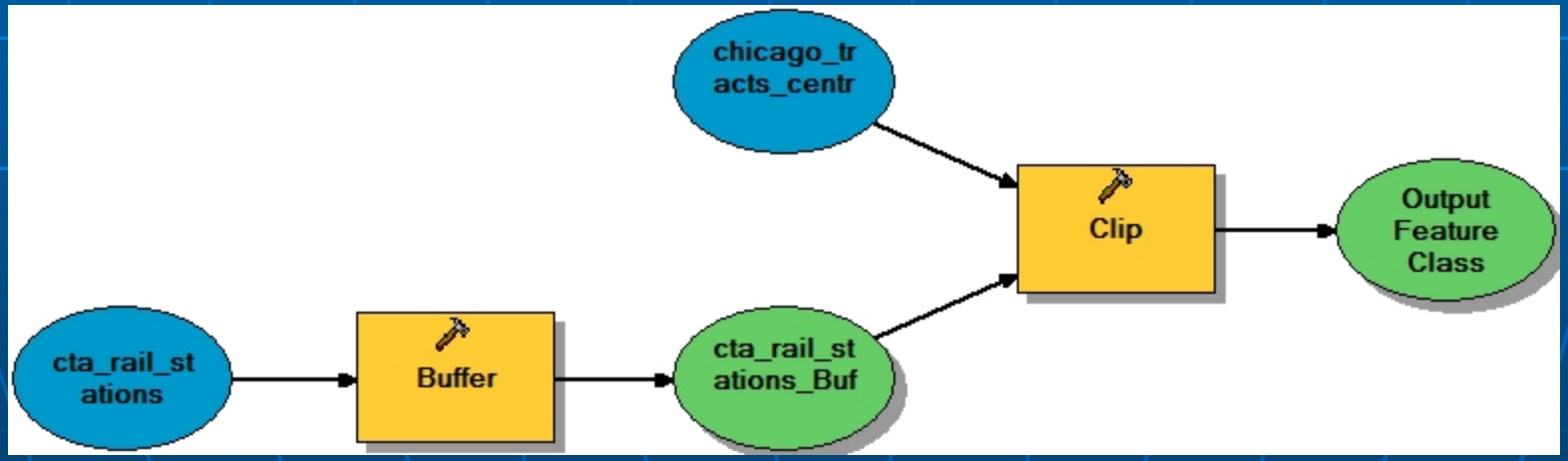
ArcGIS ModelBuilder

- Graphic environment to build a geoprocessing workflow
- Use existing tools to create a new framework
  - New framework will serve as the basis for your script



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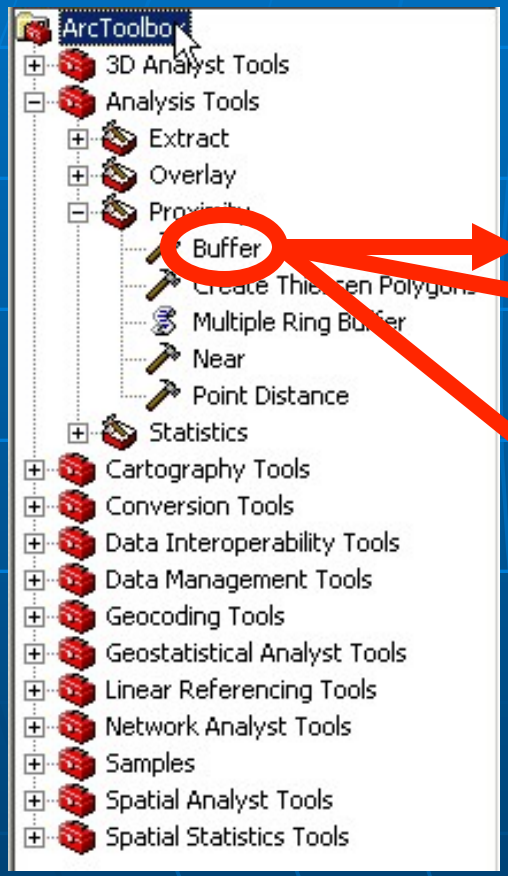
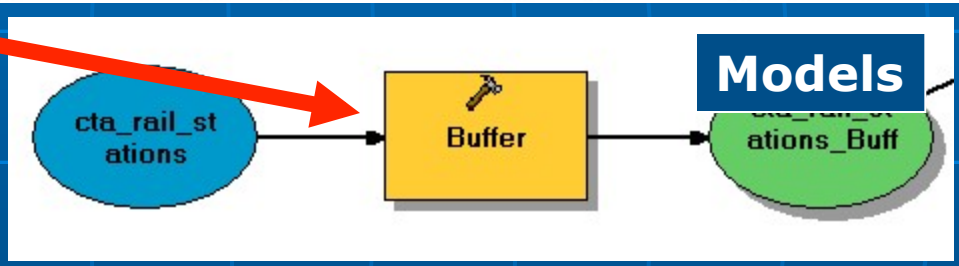
ArcGIS ModelBuilder



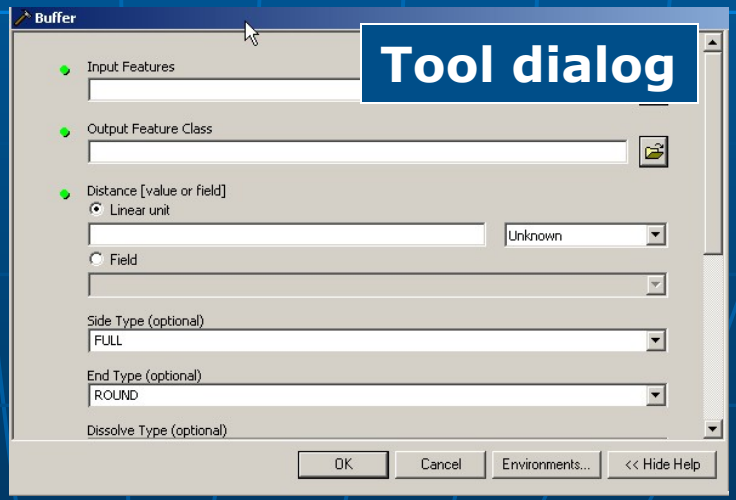
Scripts

```
# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Analysi

# Local variables...
cta_rail_stations = "C:\\stuff\\ILGISA\\cta_study.mdb\\cta_rail_stations"
chicago_tracts_centroids = "C:\\stuff\\ILGISA\\cta_study.mdb\\chicago_tracts_centro
Output_Feature_Class = "C:\\stuff\\ILGISA\\cta_study.mdb\\chicago_tracts_centroids_
cta_rail_stations_Buffer = "C:\\stuff\\ILGISA\\cta_study.mdb\\cta_rail_stations_Bu

# Process: Buffer...
gp.Buffer_analysis(cta_rail_stations, cta_rail_stations_Buffer, "1 Miles", "FULL",
```

Models



Tool dialog



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ArcGIS ModelBuilder

- Basic steps to begin scripting
  1) Create new toolbox
  2) Create new model within toolbox
  3) Build a model (as complete as possible)
  4) Test model in ModelBuilder
  5) Export script to Python for more modification

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ArcGIS ModelBuilder

- Searching for more help on ModelBuilder?
  - HELP MENU
  - Search terms: model builder
  - http://resources.arcgis.com
  - Textbook: Getting to Know ArcGIS Modelbuilder

- **DATA WARNING** when using ModelBuilder or scripting in Python: USE GEODATABASE
  - Using shapefiles and coverages is not suggested or encouraged…can cause problems
  - SDE geodatabase, file geodatabase, personal geodatabase

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Translating Python

- ModelBuilder produces Python scripts in a specific format
  - Description, software and library settings, variable settings, functions
- Descriptions
  - Name of script
  - When it was created
  - Generated by ModelBuilder
- Import system modules or libraries
  - Statement references how Python will communicate with its libraries and operating system
  - http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Importing_ArcPy/002z00000008000000/

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Translating Python

- ArcGIS 10.x:

```
# Import arcpy module
import arcpy
```

- ArcPy opens modules including:
  - Data access module (`arcpy.da`)
  - Mapping module (`arcpy.mapping`)
  - Geostatistical Analyst module (`arcpy.ga`)
  - ArcGIS Spatial Analyst module (`arcpy.sa`)
  - ArcGIS Network Analyst module (`arcpy.na`)

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Translating Python

- `import arcpy` #imports ArcGIS geoprocessing functionality
- `import arcpy.mapping` #imports only the mapping module
- `import os` #imports Python's core operating system
- `import sys` #variables/functions used or maintained by the interpreter
- `from arcpy import env` #ability to control ArcGIS environment
  - `env.workspace = "C:\data"`
- `from arcpy.management import *` #content imported into namespace. Can use content without prefix

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Variables

- Setting variables
  - Variables must be declared before they are used in the script
  - Informs script of the type of object and its “gender”
  - Feature classes, values, etc.
- Declaring variables
  - `x = 1` or `x = 1.0` or `x = 1.11` or `x = “GIS”`
  - The type of variable is defined by the value it is assigned (integer, decimal, string, etc.)
- Manipulating variables
  - Computation (+) (-) (*) (/)
  - Concatenation
    - `x = “GIS”,y = “class” … x +“ ”+ y=‘GIS class’`

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Variables

- Changing variable types
  - Numeric and character data cannot be joined unless they are the same type
    - x=15, y = ‘Your score is: ‘
    - x + y = ERROR
  - Conversion functions
    - int(x): integer, long(x): long integer, float(x): float/decimal, str(x): character string

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Variables

- Declaring multiple variables in one line
  - x=1
  - y = 2
  - z =3
  - Can be written as….x, y, z = 1, 2, 3
- Change upper and lower case strings
  - x = “Todd”
  - x = lower(x)
  - x = upper(x)

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ArcObjects

- ArcGIS is made of many types of ArcObjects
- These include: features, layers, maps, map documents, applications
- Even tables, their fields, and rows are ArcObjects
- Each of these ArcObjects has its own properties and methods, through which it interacts with other ArcObjects
- ArcObjects can be manipulated with ArcPy

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ArcObjects

- Manipulating ArcObjects requires knowing their properties

Map

- Properties
  - Layer count
  - Name
  - Spatial
- Reference
  - Map scale
  - Extent
- Methods
  - Add layer
  - Clear selection
  - Select feature

Feature Class

- Properties
  - Shape type
  - Spatial
- Reference
  - Extent
- Methods
  - Create feature
  - Remove feature

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Environments

- We set the environment for tools to use them
- This includes setting the current workspace, output spatial reference, extent, raster analysis setting (cell size, mask)
  - `arcpy.env.workspace`
  - `arcpy.env.outputCoordinateSystem`
  - `arcpy.env.extent`
  - `arcpy.env.cellSize`
  - `arcpy.evn.mask`

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Environments

- Add buffer around the road feature class with given distances

```
import arcpy
arcpy.env.workspace = "C:\data\City.gdb" #sets the workspace
fc = "Roads" #variable feature class
distanceList = ["100 meters", "200 meters", 400 meters"] #distances
```

- Loops through each distance in the distanceList
- Takes the first distance and puts it in variable dist, and repeats it 3 times

```
for dist in distanceList:
    outName = fc+" _"+ dist
    arcpy.Buffer_analysis (fc, outName, dist)  #outputs the feature class, its output name_distance
    # breaks out of the loop
print "Buffering completed!"
```

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Python Syntax

- Straight-forward and logical
  - `#` designates a comment line
  - `print` designates a print statement
- Normal mathematical operators
  - +, -, =, /, *, >, <, etc.
- Character string operators
  - “ ”, ‘ ’ …designate a string
  - +, & …concatenate
  - ==…equivalent

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Python Syntax

- Python uses whitespace and indents to denote blocks of code
- Lines of code that begin a block end in a colon:
- Lines within the code block are indented at the same level
- To end a code block, remove the indentation

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Python Syntax

- A colon and line indentation designates nesting

```
#This script will calculate distance.
for x in range(10):
    distance = 2 * x
    print distance
print "I learn so much at GIS conferences."
```

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Translating Python

- Calling functions
  - Very similar to calling functions from a command line
  - Help menu provides syntax for ALL functions
  - Ex. Buffer function
    - Buffer_analysis (in_features, out_feature_class, buffer_distance_or_field, line_side, line_end_type, dissolve_option, dissolve_field)

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Functions

- Functions perform useful tasks
  - Accessing geoprocessing tool messages (**GetMessages**)
  - Listing data for batch processing
    - **ListFeatureClasses, ListFields**, plus nine other list functions
  - Retrieving a dataset's properties (**Describe**)

```
import arcpy
# Set the workspace for ListFeatureClasses function
arcpy.env.workspace = "c:/test"

# For each feature class, create a scratch name and clip
for fc in arcpy.ListFeatureClasses ():
   outName = arcpy.CreateScratchName ("clipped_" + fc, "",
   "featureclass", arcpy.env.workspace)
   arcpy.Clip_analysis(fc, "boundary", outName)
```

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Dealing with Functions/Methods

- Assigning a value to a property:

```
#object.property = value
env.workspace = "C:/Temp"
```

- Return the value of a property:

```
#object.property
print "The workspace is " + env.workspace
```

- Use a method:

```
#object.method (arg1, arg2, …)  e.g., put
a buffer for a road:
arcpy.Buffer_analysis("c:/input/
roads.tif","c:/output.gdb/buffer_output",
"100")
```

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Describe Function

- Takes some feature class, table, raster image (e.g., properties: type, number of bands, resolution), database, workspace, and describe it
  - Find how many fields a table has, what is their type and name
- Returns an object with dynamic properties
- Allows script to determine properties of data
  - Data type (shapefile, coverage, network dataset, etc)
  - Shape type (point, polygon, line)
  - Spatial reference
  - Extent of features
  - List of fields

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Describe Function

- Returns the shape type (point, line, polygon) of a feature class

```
desc = arcpy.Describe (featureClass)
```

OR

```
d = arcpy.Describe ("c:/base.gdb/rivers")
```

- Branches based on input's shapeType property:

```
if d.shapeType == "polygon":
    arcpy.FeatureToLine_management (inFC, outFC)
else:
    arcpy.CopyFeatures_management (inFC, outFC)
```

- Print selected feature class properties

```
print "shapeType". desc.shapeType
print "the first field's name", desc.fields[0].name
print "the first field's type", desc.fields[0].type
```

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List Functions

- Get a list of feature classes, tables, rasters, etc.
- Process data using a loop through the list

```
#returns a list of feature classes, tables
#for examples all the tables in a geodatabase, or
   fields in a table
   fcList = arcpy.ListFeatureClasses()
# copy shapefiles to a file geodatabase one item at
   a time
# loop through the list of shape files using copy
   management tool
       for fc in fcList:
       arcpy.Copy_management (fc, “d/base/output.gdb”
   + os.set + fc.rstrip(“ .shp”))
```

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List Functions

- Adding to the List
  - var[*n*] = *object*
    - replaces *n* with *object*
  - var.append(*object*)
    - adds *object* to the end of the list
- Removing from the List
  - var[*n*] = []
    - empties contents of card, but preserves order
  - var.remove(*n*)
    - removes card at *n*
  - var.pop(*n*)
    - removes *n* and returns its value

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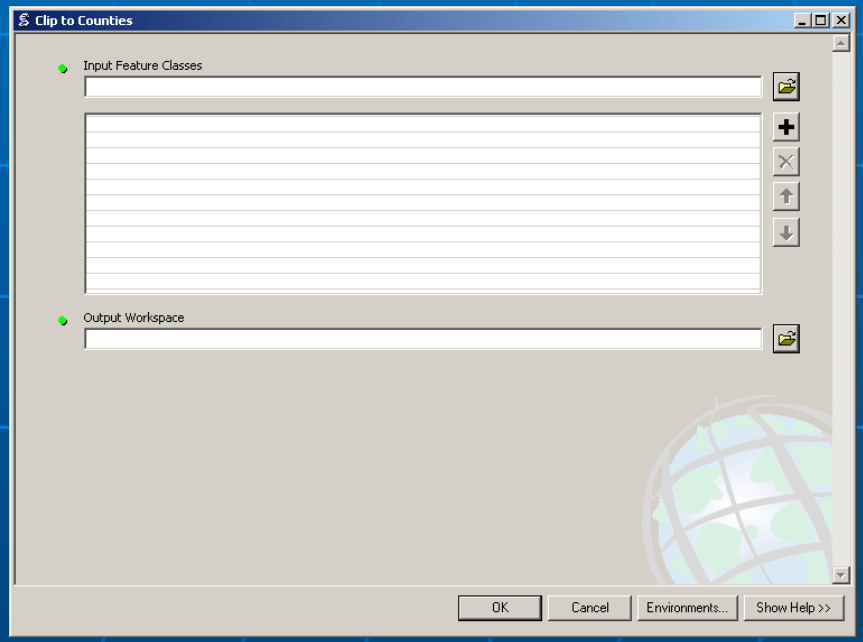
Lists in ArcToolbox

You will create lists:

- Layers as inputs
- Attributes to match
- Arrays of objects

You will work with lists:

- List of field names
- List of selected features



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Conditional Statements

- Conditional and nested conditional statements
  - `for/in` statements
  - `if/else` statements
  - `try/except` statements
  - `while` statements

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Conditional Statements

- `for/in` statements very good for cycling through variables
  - `for <variable> in <sequence>:`
    - `<body>`
  - `for x in range (10):`
    - Will repeat body of program 10 times
  - `for x in [0,1,2,3]:`
  - `for x in [A, B, C, D]:`
- The variable is set to the specific sequence value until it returns to the beginning of the loop

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Conditional Statements

- **if/else** statements performs conditional functions

```
if <true_statement>:
    <body>
else:
    <body>
```

- **if/else** can be modified for multiple conditionals with **if/elif**

```
if <true_statement>:
    <body>
elif <true_statement>:
    <body>
elif <true_statement>:
    <body>
```

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Conditional Statements

- **if/else** example asking for user input

```
answer = input("What is 1+1?")
if answer == 2:
    print "Good job."
else:
    print "Can you spell GIS?"
```

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Conditional Statements

- **while** statements run a nested loop until a statement is violated

```
while <true statement>:
    <body>
```

- Usually prefaced by setting a variable or a condition to violate

```
x = 0
while x >= 0:
    <body>
```

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Conditional Statements

- `try/except` statements good for error handling
  - If error occurs while running a function in a `try` block, `except` block takes over
  - Usually returns a message, kicks out of script, resets variables, etc.
- Diagnosing an error is another issue

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Error Capture

- Check for type assignment errors, items not in a list, etc.
- Try & Except

  try:

  a block of code that might have an error

  except:

  code to execute if an error occurs in "try"
- Allows for graceful failure
  - important in ArcGIS

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Error Messages

- When executing a tool, usually 3 types of messages:
  - Informative messages
  - Warning messages
  - Error messages

```
try:
#start try block
  arcpy.Buffer (“C:/ws/roads.shp”,“C:/outws/roads10.shp”, 10)
#print the tool messages
except arcpy.ExecuteError:
  print arcpy.GetMessages (2)
```

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Using Cursors

- Cursors allows the user to access, update, or create data records through the script
- Three types of cursors
  - Search cursor
    - Read-only access
  - Update cursor
    - Read/write/delete access, no new records
  - Insert cursor
    - Read/write access with data creation if necessary
- Row objects work with cursors to track which records are being edited

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Python Syntax

- Working with tabular calculations
  - Function: `SearchCursor`
  - Function: `InsertCursor`
    - `newRow`
    - `insertRow`
  - Function: `UpdateCursor`
    - `updateRow`
    - `deleteRow`

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Accessing Data with Cursors

- There are three types of cursors
  - Search Cursor
    - Read-only access
  - Update Cursor
    - Read/Write/Delete access but no new records
  - Insert Cursor
    - Read/Write access with capability of creating new records

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Accessing Data with a Search Cursor

- A row object is returned from the search cursor object
- Fields are accessed as properties of the row object
- Use the row object's GetValue and SetValue methods if your field name is a variable
- Destroy the row and cursor objects to remove read locks on the data source

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Accessing Data with a Search Cursor

```
rows = arcpy.SearchCursor("D:/St_Johns/data.gdb/roads")
for row in rows:
# Print concatenated values of road name and road type
    print row.name + row.getValue("type")
# Delete the row and cursor objects so no locks remain
del row
del rows
```

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Accessing Data with Cursors

- A where clause may be used to limit the records returned by the cursor
  - Same as defining a definition query on a layer

```
rows = arcpy.SearchCursor("D:/St_Johns/data.gdb/roads",
                          "[neighborhood] = "Shea_Heights")
# Print concatenated values of road name and road type
for row in rows:
   print row.name + row.getValue("type")
del row
del rows
```

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Insert Cursor

- Create a new geometry

```
cur = arcpy.InsertCursor (fc)
```

- Create array and point objects

```
ptList = [arcpy.Point (358331, 5273193), arcpy.Point
(358337, 5272830)]
lineArray = arcpy.Array(ptList)
```

- Create a new row for the feature class

```
feat = cur.newRow ()
#set the geometry of the new feature to the array
points
feat.Shape = lineArray
#Insert the feature
cur.insertRow (feat)
#Delete objects
del cur, feat
```

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Geometry Objects

- Create, delete, move, and reshape features
  - Create a geometry object and put it in the variable g

```
g = arcpy.Geometry ()
```

  - Run the Copy Features tool. set the output to the geometry object
  - Return a list of geometry objects (lines, streets)

```
geometryList = arcpy/CopyFeatures_management (“c:/data/
  streets.shp”, g)
```

  - Loop through each geometry, totaling the lengths of the streets

```
for geometry in geometryList:
  length += geometry.length #Note: x +=1 means x=x+1
  print “Total length: %f” % length
```

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Mapping module

- **arcpy.mapping**
  - Used to open and manipulate existing map documents (.mxd) and layer files (.lyr)
- **Query and alter the contents of a map**
  - Find a layer with data source X and replace with Y
  - Updata a layer's symbology across many MXDs
  - Generate a report listing document information
    - Data sources, broken layers, spatial reference, etc.
- Can print, export, or save the modified document
- Allows adding, removing, and rotating data frames, and adding and removing layers
- Manipulate properties of map documents and layers

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Manipulate map documents

Modify map document properties, save changes to a layer file, and save changes to the map document

```
import arcpy
mxd = arcpy.mapping.MapDocument ("input.mxd")
df = arcpy.mapping.ListDataFrames (mxd)
df.scale = 24000
df.rotation = 2.7

for lyr in arcpy.mapping.ListLayers(mxd):
  if lyr.name == "Landuse":
    lyr.visible = True
    lyr.showLabels = True
    lyr.saveACopy("output.lyr")
mxd.save()
del mxd
```

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Manipulating Layers

- Change properties of a layer
  - Name, source data, visibility (make it on or off), transparency, label, definition query, display order, etc.

```
import arcpy
lyrFile = arcpy.mapping.Layer ("C:
  \Project\Date\Streets.lyr")

for lyr in arcpy.mapping.ListLayers(lyrFile):
  if lyr.name.lower() == "highways":
#turn its label on
    lyr.showLabels = True
    lyr.saveACopy (r"C:
  \Project\Data\StreetsWithLabels.lyr")
#now the changed layer is saved as different layer
del lyrFile
```

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Adding a Python Script as a Tool

- Add a script as a tool to a toolbox
- They become a new tool with all the properties of a tool, e.g.,
  - It will return messages, access to all environment settings, and automatically add the output to our map (to the table of contents in ArcMap)
- Can easily be shared
- Tools automatically create dialog boxes (created by ArcGIS)
- Add the tool into the toolbar and menus

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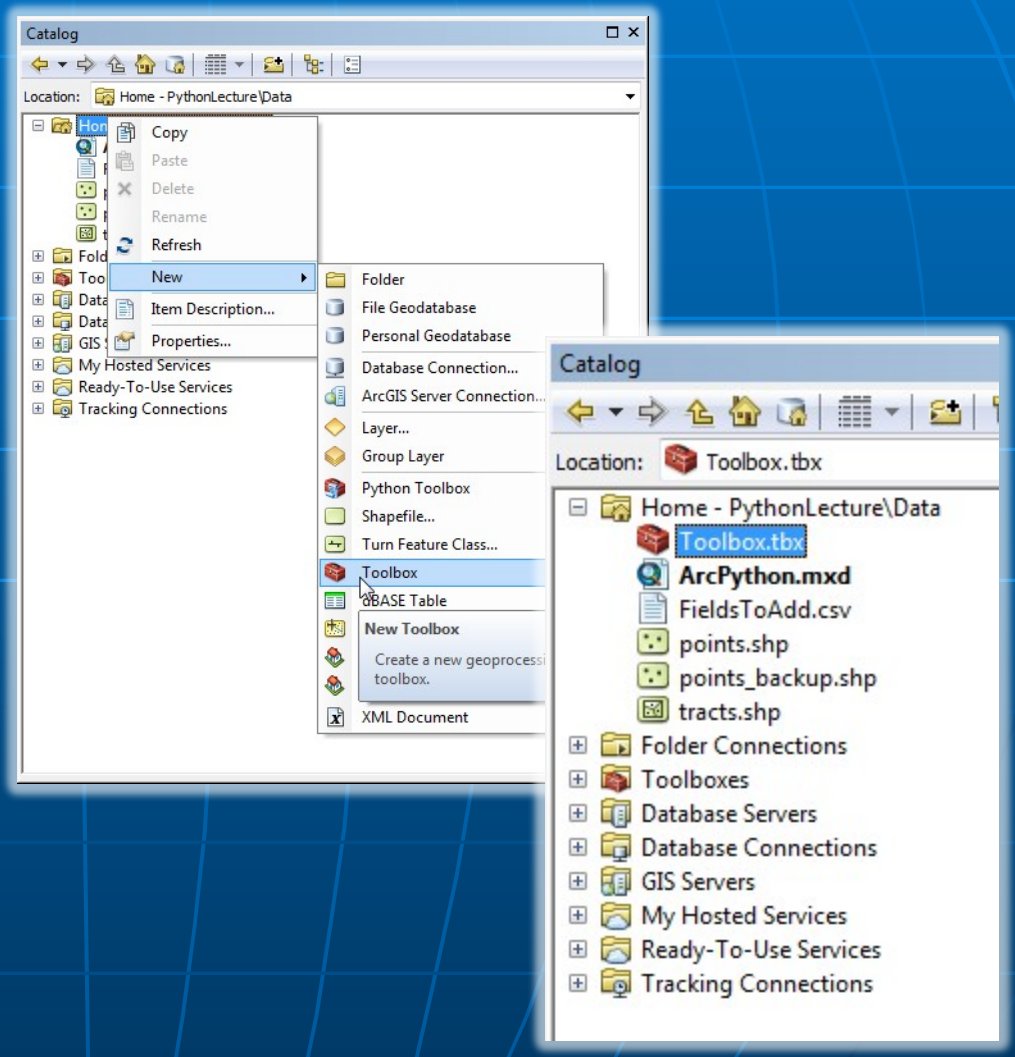
Creating a Custom Toolbox

- Empty custom toolboxes can be made in the *Catalog* pane.
- Each toolbox can contain multiple tools
- Each tool references a Python script file with the *.py* extension.



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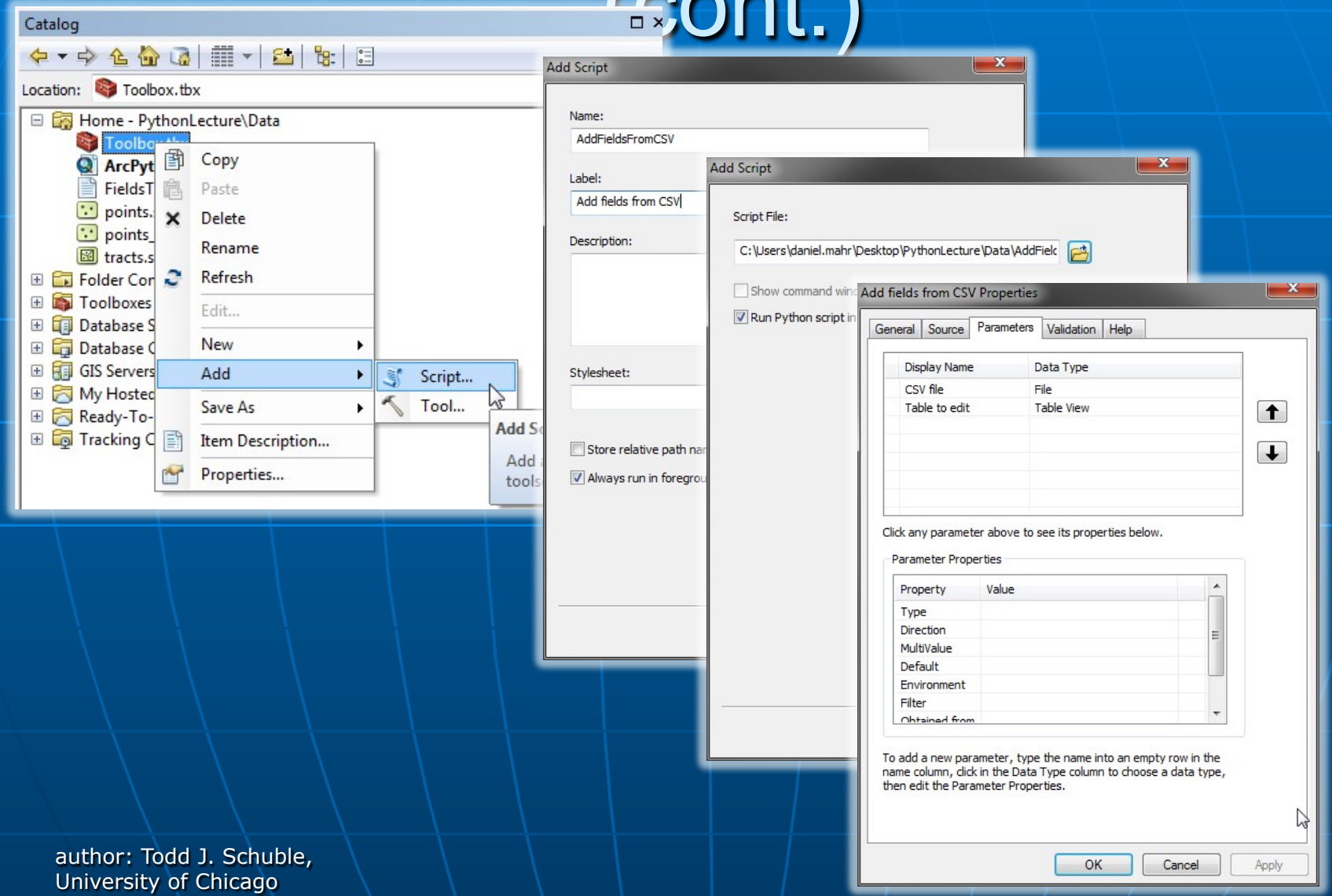
Creating a Custom Toolbox (cont.)



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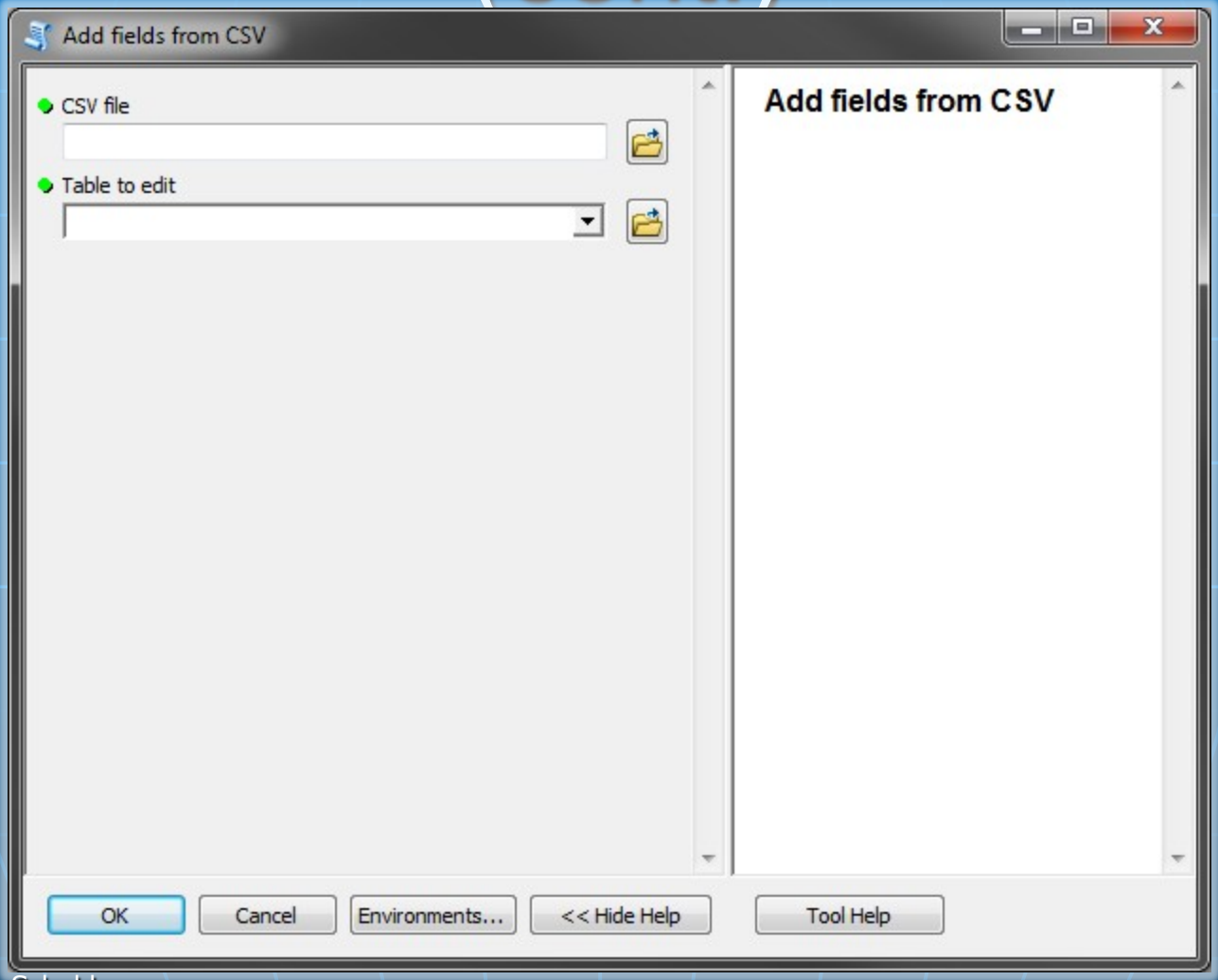
Creating a Custom Toolbox (cont.)



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Creating a Custom Toolbox (cont.)

AddFields.py - C:\Users\daniel.mahr\Desktop\PythonLecture\Data\AddFields.py

File Edit Format Run Options Windows Help

```
import csv
reader = csv.reader(open("C:\Users\daniel.mahr\Desktop\PythonLecture\Data\FieldsToAdd.csv","rb"))
for row in reader:
    if row[0].startswith("Field"):
        arcpy.AddField_management("points",row[0],row[1])
```

AddFields.py - C:\Users\daniel.mahr\Desktop\PythonLecture\Data\AddFields.py

File Edit Format Run Options Windows Help

```
import csv, arcpy
fields_csv = arcpy.GetParameterAsText(0)
table = arcpy.GetParameterAsText(1)
reader = csv.reader(open(fields_csv,"rb"))
reader.next()
for row in reader:
    arcpy.AddField_management(table,row[0],row[1])
```

1. Import arcpy module
2. Handle header fields more elegantly using `next()`
3. Use parameter values from our toolbox tool instead of hardcoded .csv file and table layer.

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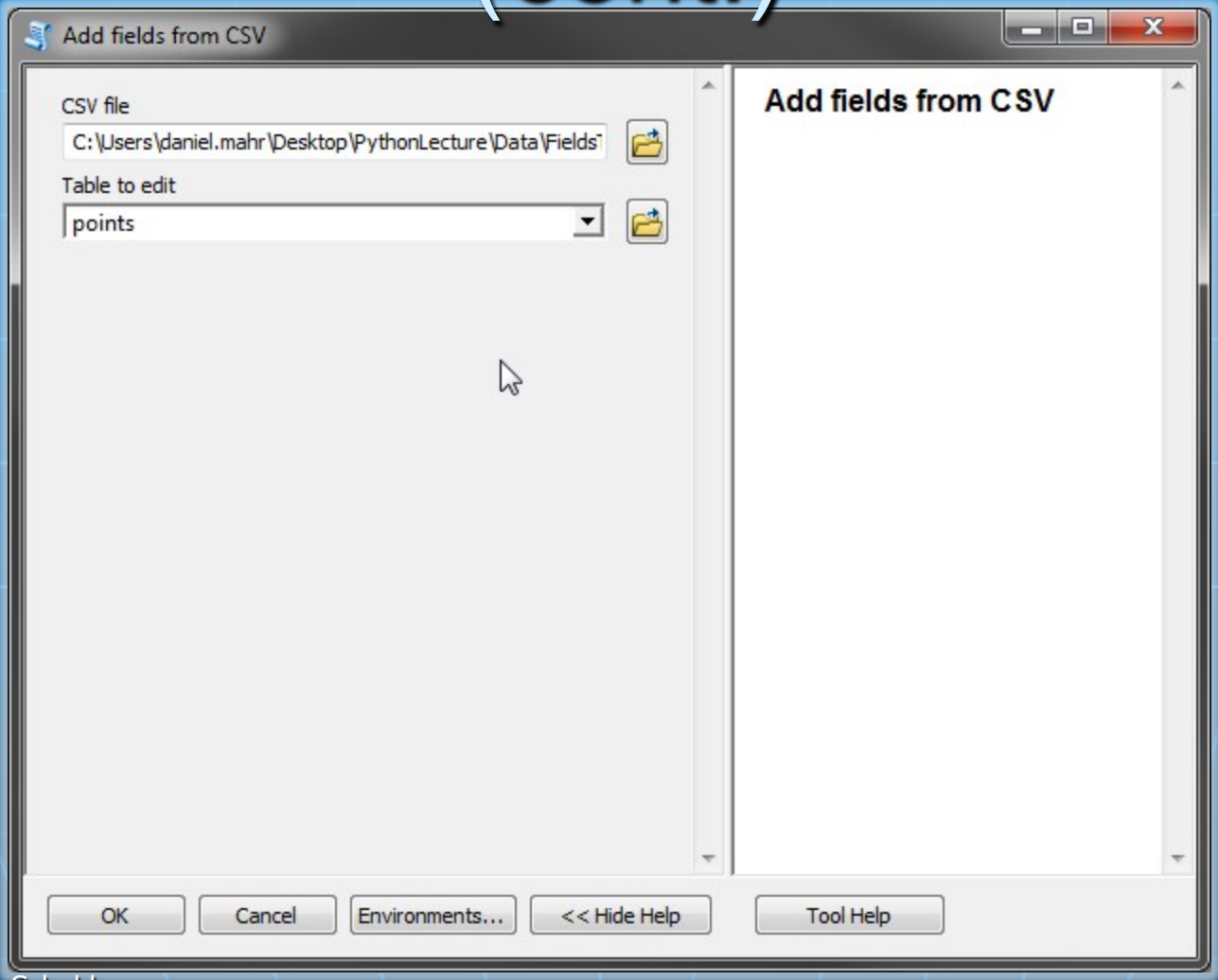
Creating a Custom Toolbox (cont.)



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Read/Write to Files

- Files are manipulated by creating a file object
  - `f = open("points.txt", "r")`
- The file object then has new methods
  - `print f.readline() # prints line from file`
- Files can be accessed to read or write
  - `f = open("output.txt", "w")`
  - `f.write("Important Output!")`
- Files are iterable objects, like lists

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