

INTRO TO R FOR MATH 2510 PROJECT

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University of Colorado at Boulder

Monday, April 29, 2019

DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from R-Studio.com

<https://www.rstudio.com/products/rstudio/download/>

The screenshot shows the R-Studio website at https://www.rstudio.com/products/rstudio/download/. The page title is "Choose Your Version of RStudio". It describes RStudio as a set of integrated tools for productivity with R, including a console, syntax-highlighting editor, and plotting tools. It lists five versions with their prices and download links:

RStudio Desktop Open Source License	RStudio Desktop Commercial License	RStudio Server Open Source License	RStudio Server Pro Commercial License	RStudio Server Pro + RStudio Connect Commercial License
FREE	\$995 per year	FREE	\$9,995 per year	\$29,995 per year
DOWNLOAD Learn More	BUY Learn More	DOWNLOAD Learn More	DOWNLOAD Learn More	TALK Learn More

A progress bar at the bottom indicates the user is on step 1 of 5. The URL in the address bar is https://www.rstudio.com/products/rstudio/download#download.



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DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from R-Studio.com – Mac Users

<https://www.rstudio.com/products/rstudio/download/>

The screenshot shows a web browser window with the URL <https://www.rstudio.com/products/rstudio/download/#download>. The page header includes the RStudio logo and navigation links for Products, Resources, Pricing, About Us, and Blogs. A search bar is also present. Below the header, a message states: "RStudio requires R 3.0.1+. If you don't already have R, download it [here](#)." Another note for Linux users says: "Linux users may need to import RStudio's public code-signing key prior to installation, depending on the operating system's security policy." A section titled "Installers for Supported Platforms" lists various RStudio versions for different platforms, each with a download link, size, date, and MD5 hash. The table includes rows for Windows 7+, Mac OS X 10.12+, Ubuntu 14/Debian 8, Ubuntu 16, Ubuntu 18, RedHat 7+, Fedora 19+, Debian 9+, OpenSUSE 15+, and SLES/OpenSUSE 12+. At the bottom of the page, there is a footer for the Department of Mathematics at the University of Colorado Boulder, featuring their logo and contact information.

Installers	Size	Date	MD5
RStudio 1.2.1335 - Windows 7+	126.9 MB	2019-04-08	d0e2470f1f8ef4cd35a669aa323a2136
RStudio 1.2.1335 - Mac OS X 10.12+ (64-bit)	121.1 MB	2019-04-08	6c570b0e2144583f7c48c284ce299ee5
RStudio 1.2.1335 - Ubuntu 14/Debian 8 (64-bit)	92.2 MB	2019-04-08	c1b07d0511469abfe582919b183eee83
RStudio 1.2.1335 - Ubuntu 16 (64-bit)	99.3 MB	2019-04-08	c142d69c210257fb10d18c045fff13c7
RStudio 1.2.1335 - Ubuntu 18 (64-bit)	100.4 MB	2019-04-08	71a8d1990c0d97939804b46cfb0aea75
RStudio 1.2.1335 - Fedora 19+/RedHat 7+ (64-bit)	114.1 MB	2019-04-08	296b6ef88969a91297fcb6545f256a7a
RStudio 1.2.1335 - Debian 9+ (64-bit)	100.6 MB	2019-04-08	1e32d4d6f6e216f086a81ca82ef65a91
RStudio 1.2.1335 - OpenSUSE 15+ (64-bit)	101.6 MB	2019-04-08	2795a63c7efd8e2aa2daea86ba09a81e5
RStudio 1.2.1335 - SLES/OpenSUSE 12+ (64-bit)	94.4 MB	2019-04-08	c65424b06ef7d737279d982db9eefcae1

DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from R-Studio.com – Windows Users

<https://www.rstudio.com/products/rstudio/download/>

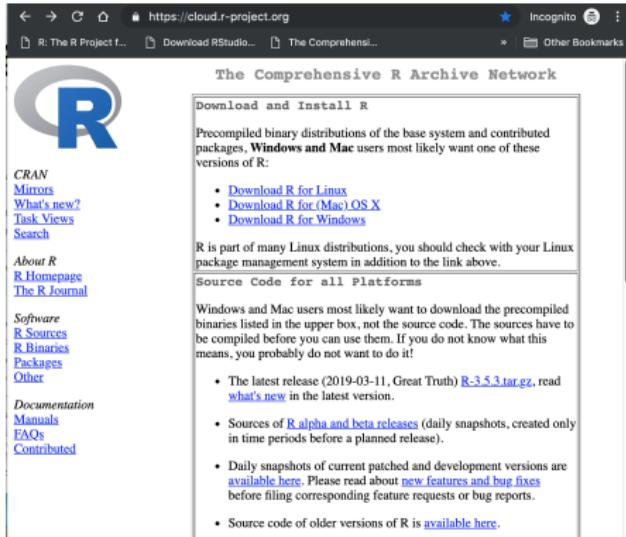
The screenshot shows the RStudio download page. At the top, there's a navigation bar with links for Products, Resources, Pricing, About Us, and Blogs. Below the navigation bar, a message says "RStudio requires R 3.0.1+. If you don't already have R, download it [here](#)." Another message for Linux users mentions importing a public code-signing key. The main content area is titled "Installers for Supported Platforms" and contains a table with the following data:

Installers	Size	Date	MDS
RStudio 1.2.1335 - Windows 7 ⁴	126.9 MB	2019-04-08	d0e2470f1f8ef4cd35a669aa323a2136
RStudio 1.2.1335 - Mac OS X 10.12+ (64-bit)	121.1 MB	2019-04-08	6e570b0e2144583f7c48c284ce299eeff
RStudio 1.2.1335 - Ubuntu 14/Debian 8 (64-bit)	92.2 MB	2019-04-08	c1b07d0511469abfe582919b183eee83
RStudio 1.2.1335 - Ubuntu 16 (64-bit)	99.3 MB	2019-04-08	c142d69c210257fb10d18c045fff13c7
RStudio 1.2.1335 - Ubuntu 18 (64-bit)	100.4 MB	2019-04-08	71a8d1990c0d97939804b46cfb0aea75
RStudio 1.2.1335 - Fedora 19+/RedHat 7+ (64-bit)	114.1 MB	2019-04-08	296b6ef88969a91297fab6545f256a7a
RStudio 1.2.1335 - Debian 9+ (64-bit)	100.6 MB	2019-04-08	1e32d4d6f6e216f086a81ca82ef65a91
RStudio 1.2.1335 - OpenSUSE 15+ (64-bit)	101.6 MB	2019-04-08	2795a63c7efd8e2aa2dae86ba09a81e5
RStudio 1.2.1335 - SLES/OpenSUSE 12+ (64-bit)	94.4 MB	2019-04-08	c65424b06ef6737279d982db9eefcae1

At the bottom right, there's a logo for the Department of Mathematics at the University of Colorado Boulder.

DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from <https://www.r-project.org/>
<https://cloud.r-project.org/>



The screenshot shows the CRAN homepage with a navigation bar at the top. Below the navigation, there's a large 'R' logo. On the left, there's a sidebar with links for 'CRAN', 'Mirrors', 'What's new?', 'Task Views', 'Search', 'About R', 'R Homepage', 'The R Journal', 'Software', 'R Sources', 'R Binaries', 'Packages', 'Other', 'Documentation', 'Manuals', 'FAQs', and 'Contributed'. The main content area has a title 'The Comprehensive R Archive Network' and a sub-section 'Download and Install R'. It says: 'Precompiled binary distributions of the base system and contributed packages, Windows and Mac users most likely want one of these versions of R:' followed by a list: 'Download R for Linux', 'Download R for (Mac) OS X', and 'Download R for Windows'. It also notes: 'R is part of many Linux distributions, you should check with your Linux package management system in addition to the link above.' Below this is another section titled 'Source Code for all Platforms' which discusses source code availability for Windows and Mac users.



DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from [https://cloud.r-project.org/](https://cloud.r-project.org)
Mac Users

The screenshot shows a Mac OS X desktop with a browser window open to <https://cloud.r-project.org>. The title bar says "The Comprehensive R Archive". A download progress bar at the top indicates "Save As: R-3.5.3.pkg" is in progress. The main content area shows a file list with "R-3.5.3.pkg" selected. Below the file list, there's a "Format:" dropdown set to "Installer package archive" and a "Save" button. To the left, a sidebar lists "Software", "R Sources", "R Binaries", "Packages", "Other", "Documentation", "Manuals", "FAQs", and "Contributed". On the right, there's a "Latest release:" section for R 3.5.3, which includes a link to the file, its MD5 hash, and a note about X11 requirements. At the bottom, there's a "NEWS" section for Mac GUI and a footer for the Department of Mathematics at CU Boulder.

Save As: R-3.5.3.pkg

Tags:

Downloads

Today

R-3.5.3.pkg

Previous 30 Days

Abel.pdf

Calculus_10e_Bernard.pdf

Format: Installer package archive

Cancel Save

validate the signature using
pkutil --check-signature R-3.5.3.pkg

Latest release:

R 3.5.3 [R-3.5.3.pkg](#)
MD5 hash: 49fb095b2b6f68729e48319852c
SHA1:
hash: 1139370ad397072e1784b6c735d21a1328c
(ca. 74MB)

R 3.5.3 binary for OS X 10.11 (El Capitan) and higher, signed package.
Contains R 3.5.3 framework, R.app GUI 1.70 in 64-bit for Intel Macs, Tcl/Tk
8.6.6 X11 libraries and Texinfo 5.2. The latter two components are optional
and can be omitted when choosing "custom install", they are only needed if
you want to use the `tkR` package or build package documentation from
sources.

Note: the use of X11 (including `tkR`) requires [XQuartz](#) to be installed since
it is no longer part of OS X. Always re-install XQuartz when upgrading your
macOS to a new major version.

Important: this release uses Clang 6.0.0 and GNU Fortran 6.1, neither of
which is supplied by Apple. If you wish to compile R packages from sources,
you will need to download and install those tools - see the [tools](#) directory.

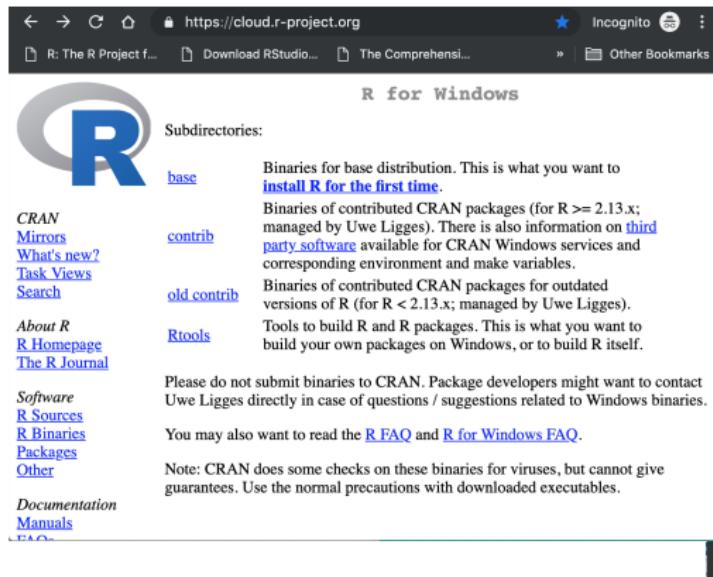
NEWS (for Mac GUI)

News features and changes in the R.app Mac GUI

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DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from <https://cloud.r-project.org/>
Windows Users



The screenshot shows a web browser window with the URL <https://cloud.r-project.org/> in the address bar. The page title is "R for Windows". On the left, there's a large blue "R" logo and a sidebar with links like CRAN, Mirrors, What's new?, Task Views, Search, About R, R Homepage, and The R Journal. The main content area is titled "Subdirectories:" and lists several options:

- base**: Binaries for base distribution. This is what you want to [install R for the first time](#).
- contrib**: Binaries of contributed CRAN packages (for R >= 2.13.x; managed by Uwe Ligges). There is also information on [third party software](#) available for CRAN Windows services and corresponding environment and make variables.
- old_contrib**: Binaries of contributed CRAN packages for outdated versions of R (for R < 2.13.x; managed by Uwe Ligges).
- Rtools**: Tools to build R and R packages. This is what you want to build your own packages on Windows, or to build R itself.

Below these, there's a note: "Please do not submit binaries to CRAN. Package developers might want to contact Uwe Ligges directly in case of questions / suggestions related to Windows binaries." It also suggests reading the [R FAQ](#) and [R for Windows FAQ](#). A note at the bottom states: "Note: CRAN does some checks on these binaries for viruses, but cannot give guarantees. Use the normal precautions with downloaded executables."

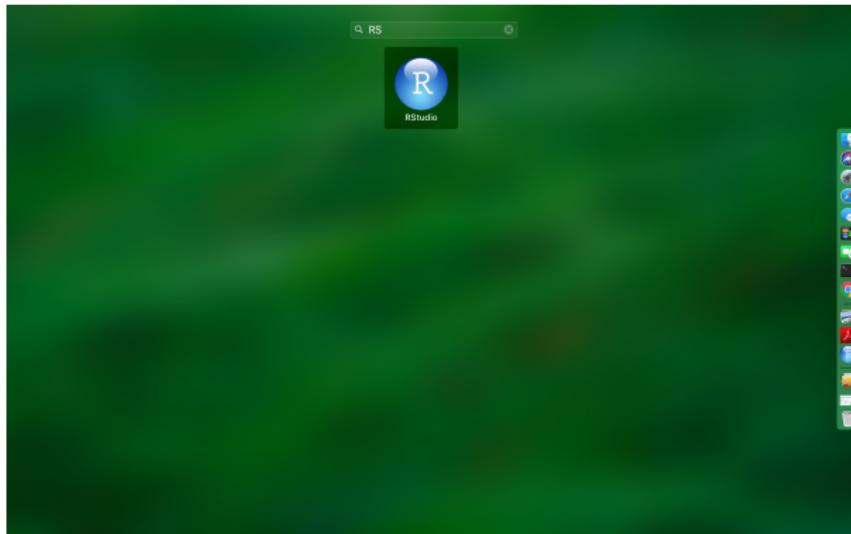
DOWNLOAD AND INSTALL R IN YOUR COMPUTER

Download R from <https://cloud.r-project.org/>
Windows Users

The screenshot shows a web browser window with the URL <https://cloud.r-project.org/> in the address bar. The main content is titled "R-3.5.3 for Windows (32/64 bit)". It features a large blue "R" logo with a grey "C" behind it. Below the logo, there's a sidebar with links like "CRAN", "Mirrors", "What's new?", "Task Views", "Search", "About R", "R Homepage", "The R Journal", "Software", "R Sources", "R Binaries", "Packages", "Other", "Documentation", "Manuals", and "FAQ". A central box contains the text "Download R 3.5.3 for Windows (79 megabytes, 32/64 bit)" with three links: "Installation and other instructions", "New features in this version", and "Frequently asked questions". Under "Frequently asked questions", there's a list of three bullet points: "Does R run under my version of Windows?", "How do I update packages in my previous version of R?", and "Should I run 32-bit or 64-bit R?". At the bottom, it says "Please see the [R FAQ](#) for general information about R and the [R Windows FAQ](#) for Windows-specific information." On the right side, there's a "Other builds" section with a note about patches and a link to "r-patched.snapshot.build.". The bottom right corner features the University of Colorado Boulder Department of Mathematics logo.

GET STARTED ON R

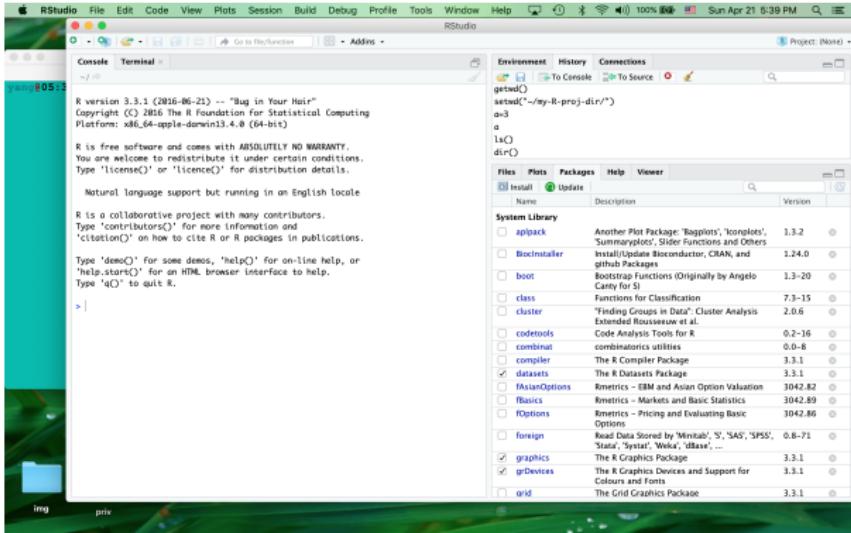
Get started on R – Mac Users
Click Launchpad and Search Studio



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GET STARTED ON R

Get started on R – Mac Users Here is the workspace you can type any R commands



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OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Names, Assignment

```
> a = 12
> A = 'MATH 2510'
> a
[1] 12
> A
[1] "MATH 2510"
> # a & A are different! case sensitive!
```

> — the beginning of an input
[1] — the beginning of an output
— comment – R will ignore anything after



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Names, Assignment

```
> a <- 12      # same as a = 12
> 12 -> a      # same as a = 12
> A = "Jack"    # same as A = 'Jack'
> A <- "Jack"    # same as A = 'Jack'
> "Jack" -> A    # same as A = 'Jack'
```



Names, Assignment

Names, Assignment

```
> 12 <- a      # not allowed!
```

```
Error in 12 <- a : invalid (do_set) left-hand s
```

```
> a = a + 12 # Is it OK?
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Names, Assignment

```
> 12 <- a      # not allowed!
Error in 12 <- a : invalid (do_set) left-hand s
> a = a + 12 # Is it OK?

> a
[1] 24          # current value of a is 24
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Names, Assignment

```
> 12 <- a      # not allowed!
Error in 12 <- a : invalid (do_set) left-hand s
> a = a + 12 # Is it OK?

> a
[1] 24          # current value of a is 24

> a = a + 12 # what is a equal to?
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Names, Assignment

```
> 12 <- a      # not allowed!
Error in 12 <- a : invalid (do_set) left-hand s
> a = a + 12 # Is it OK?

> a
[1] 24          # current value of a is 24

> a = a + 12 # what is a equal to?

> a
[1] 36          # current value of a is 36
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a = c(4, 29, 2019) # a vector with 3 components  
> a  
[1] 4 29 2019
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a = c(4, 29, 2019) # a vector with 3 components  
> a  
[1] 4 29 2019  
  
> names = c("Alice", "Bob", "Chris")  
> Names # what's going to happen if type this?
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a = c(4, 29, 2019) # a vector with 3 components  
> a  
[1] 4 29 2019  
  
> names = c("Alice", "Bob", "Chris")  
> Names # what's going to happen if type this?  
Error: object 'Names' not found
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a = c(4, 29, 2019) # a vector with 3 components  
> a  
[1] 4 29 2019  
  
> names = c("Alice", "Bob", "Chris")  
> Names # what's going to happen if type this?  
Error: object 'Names' not found  
  
> names  
[1] "Anna" "Bob" "Chris"
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a = c(4, 29, 2019) # a vector with 3 components  
> a  
[1] 4 29 2019  
  
> names = c("Alice", "Bob", "Chris")  
> Names # what's going to happen if type this?  
Error: object 'Names' not found  
  
> names  
[1] "Anna" "Bob" "Chris"
```

R object names are case sensitive!



Vector, List, or Array

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> names  
[1] "Anna"   "Bob"     "Chris"
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> names  
[1] "Anna"   "Bob"     "Chris"  
> names[1]  
[1] "Anna"  
> names[1:2]  
[1] "Anna" "Bob"  
> names[2:3]  
[1] "Bob"    "Chris"  
> names[c(1,3)]  
[1] "Anna"   "Chris"  
> names[1,3]
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> names
[1] "Anna"   "Bob"     "Chris"
> names[1]
[1] "Anna"
> names[1:2]
[1] "Anna" "Bob"
> names[2:3]
[1] "Bob"    "Chris"
> names[c(1,3)]
[1] "Anna"   "Chris"
> names[1,3]
Error in names[1, 3] : incorrect number of dimensions
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a  
[1] 4 29 2019
```

Q: insert 10 before vector *a* and assign it to *b*

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a  
[1] 4 29 2019
```

Q: insert 10 before vector *a* and assign it to *b*

```
> b = c(10, a)  
> b
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a  
[1] 4 29 2019
```

Q: insert 10 before vector *a* and assign it to *b*

```
> b = c(10, a)  
> b  
[1] 10 4 29 2019
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

```
> a  
[1] 4 29 2019
```

Q: insert 10 before vector *a* and assign it to *b*

```
> b = c(10, a)  
> b  
[1] 10 4 29 2019  
  
> c = 2:5  
> c  
[1] 2 3 4 5
```

Q: insert 10 between *a* & *c* and assign it to *b*.



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OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

Q: insert 10 between a & c and assign it to b .



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OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

Q: insert 10 between a & c and assign it to b .

```
> a  
[1] 4 29 2019  
> b  
[1] 10 4 29 2019  
> c  
[1] 2 3 4 5
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

Q: insert 10 between a & c and assign it to b .

```
> a  
[1] 4 29 2019  
> b  
[1] 10 4 29 2019  
> c  
[1] 2 3 4 5  
b = c(a,10,b)
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

Q: insert 10 between a & c and assign it to b .

```
> a  
[1] 4 29 2019  
> b  
[1] 10 4 29 2019  
> c  
[1] 2 3 4 5  
b = c(a,10,b)  
> b  
[1] 4 29 2019 10 10 4 29 2019
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Vector, List, or Array

Q: insert 10 between a & c and assign it to b .

```
> a  
[1] 4 29 2019  
> b  
[1] 10 4 29 2019  
> c  
[1] 2 3 4 5  
b = c(a,10,b)  
> b  
[1] 4 29 2019 10 10 4 29 2019
```

b is overwritten!



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Create A Random Sample

Q: How to generate a random sample from $\{1, 2, 3, 4, 5, 6\}$?

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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



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Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```



Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```



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OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```

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



Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```

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

```
> sample(1:6,size=7,replace=F) # ??
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```

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

```
> sample(1:6,size=7,replace=F) # ??
```

```
> sample(1:6,size=5,replace=F) # ??
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```

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

```
> sample(1:6,size=7,replace=F) # ??
```

```
> sample(1:6,size=5,replace=F) # ??
```

```
> sample(1:6,size=7,replace=F) # 7 different numbers from 1 to 6 are NOT possible!
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```

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

```
> sample(1:6,size=7,replace=F) # ??
```

```
> sample(1:6,size=5,replace=F) # ??
```

```
> sample(1:6,size=7,replace=F) # 7 different numbers from 1 to 6 are NOT possible!
```

```
[1] Error in sample.int(length(x), size, replace, prob) :
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6) # random sample
```

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

```
> sample(1:6,size=6,replace=T) # there might be 3 6's (T = TRUE)
```

```
[1] 6 1 6 4 6 2
```

```
> sample(1:6,size=6,replace=F) # No duplicates (F = FALSE)
```

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

```
> sample(1:6,size=7,replace=F) # ??
```

```
> sample(1:6,size=5,replace=F) # ??
```

```
> sample(1:6,size=7,replace=F) # 7 different numbers from 1 to 6 are NOT possible!
```

```
[1] Error in sample.int(length(x), size, replace, prob) :
```

```
[1] cannot take a sample larger than the population when
```

```
'replace = FALSE'
```



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Create A Random Sample

Q: How to generate a random sample from $\{1, 2, 3, 4, 5, 6\}$?

Create A Random Sample

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> sample(1:6,size=7,replace=T)
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Create A Random Sample

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[1] 4 4 5 1 6 1 5
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Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6,size=7,replace=T)
```

```
[1] 4 4 5 1 6 1 5
```

```
> sample(1:6,size=20,replace=T)
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

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```
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```

```
[1] 4 4 5 1 6 1 5
```

```
> sample(1:6,size=20,replace=T)
```

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



Create A Random Sample

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```

```
[1] 4 4 5 1 6 1 5
```

```
> sample(1:6,size=20,replace=T)
```

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

```
> x4 = c(rgamma(5800, 3))
```



OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

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```
[1] 4 4 5 1 6 1 5
```

```
> sample(1:6,size=20,replace=T)
```

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

```
> x4 = c(rgamma(5800, 3))
```

```
> x4[1] # the first element in x4
```

Q: When you run the command **x4 = c(rgamma(5800, 3))**, would **x4[1]** always be the same?



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OBJECT, ASSIGNMENT, SCALAR/VECTOR/LIST

Create A Random Sample

Q: How to generate a random sample from {1, 2, 3, 4, 5, 6}?

```
> sample(1:6,size=7,replace=T)
```

```
[1] 4 4 5 1 6 1 5
```

```
> sample(1:6,size=20,replace=T)
```

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

```
> x4 = c(rgamma(5800, 3))
```

```
> x4[1] # the first element in x4
```

Q: When you run the command **x4 = c(rgamma(5800, 3))**, would **x4[1]** always be the same?

No because x4 is randomly generated.



OPERATORS AND BUILTIN FUNCTIONS

Operators in R

Operator	Description	Operator	Description
+	addition	>	greater than
-	subtraction	\geq	greater than or equal to
*	multiplication	$=\!=$	exactly equal to
/	division	! $=$	not equal to

Some builtin functions: **sin, cos, tan, asin, acos, atan, exp, sqrt, length, sum, mean, median, sd**, etc.



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Some builtin functions: **sin, cos, tan, asin, acos, atan, exp, sqrt, length, sum, mean, median, sd**, etc.

`> 3 + 4 - 5^2 + exp(2) # = 3 + 4 - 5^2 + e^2`



OPERATORS AND BUILTIN FUNCTIONS

Operators in R

Operator	Description	Operator	Description
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```
> 3 + 4 - 5^2 + exp(2) # = 3 + 4 - 5^2 + e^2
```

```
[1] -10.61094
```



OPERATORS AND BUILTIN FUNCTIONS

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Some builtin functions: **sin, cos, tan, asin, acos, atan, exp, sqrt, length, sum, mean, median, sd**, etc.

```
> 3 + 4 - 5^2 + exp(2) # = 3 + 4 - 5^2 + e^2
```

```
[1] -10.61094
```

```
> x = c(3,3,3,4,5,5,8,12)
```

Q: Find the **length, sum, mean, median** and **std dev.** of **x**



OPERATORS AND BUILTIN FUNCTIONS

Basic Statistics Functions

```
> x = c(3,3,3,4,5,5,8,12)
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Basic Statistics Functions

```
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```

Q: Find the **length**, **sum**, **mean**, **median** and **std dev.** of **x**

```
> length(x) # length of x
```



Basic Statistics Functions

```
> x = c(3,3,3,4,5,5,8,12)
```

Q: Find the **length**, **sum**, **mean**, **median** and **std dev.** of **x**

```
> length(x) # length of x
```

```
[1] 8
```



Basic Statistics Functions

```
> x = c(3,3,3,4,5,5,8,12)
```

Q: Find the **length**, **sum**, **mean**, **median** and **std dev.** of **x**

```
> length(x) # length of x
```

```
[1] 8
```

```
> sum(x) # the sum of x or  $\Sigma x$ 
```



Basic Statistics Functions

```
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```

```
[1] 8
```

```
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```

```
[1] 43
```



Basic Statistics Functions

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```

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```

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[1] 8
```

```
> sum(x) # the sum of x or  $\Sigma x$ 
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```
[1] 43 > mean(x) # the average or mean of x, or  $\bar{x} = \frac{\Sigma x}{n}$ 
```



Basic Statistics Functions

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> x = c(3,3,3,4,5,5,8,12)
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```
[1] 5.375
```



OPERATORS AND BUILTIN FUNCTIONS

Basic Statistics Functions

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> median(x) # the median of x
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OPERATORS AND BUILTIN FUNCTIONS

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```

```
[1] 5.375
```

```
> median(x) # the median of x
```

```
[1] 4.5
```



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OPERATORS AND BUILTIN FUNCTIONS

Basic Statistics Functions

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> x = c(3,3,3,4,5,5,8,12)
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```
[1] 5.375
```

```
> median(x) # the median of x
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```
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```

```
> sd(x) # the sample standard deviation of x =  $\sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$ 
```



OPERATORS AND BUILTIN FUNCTIONS

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[1] 3.159453
```



OPERATORS AND BUILTIN FUNCTIONS

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```

```
[1] 3.159453
```

```
> sqrt( sum((x-mean(x))^2)/(length(x)-1) )
```



OPERATORS AND BUILTIN FUNCTIONS

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NORMAL DISTRIBUTIONS

pnorm, qnorm, dnorm

pnorm	p for “probability”
qnorm	q for “quantile”
dnorm	d for “density”



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NORMAL DISTRIBUTIONS

pnorm, qnorm, dnorm

pnorm	p for “probability”
qnorm	q for “quantile”
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Q: Find $P(z < -1.5)$, i.e., the probability of $z < -1.5$ with standard normal distribution (mean $\mu = 0$, stdev $\sigma = 1$)



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Q: Find $P(z < -1.5)$, i.e., the probability of $z < -1.5$ with standard normal distribution (mean $\mu = 0$, stdev $\sigma = 1$)

```
> pnorm(-1.5) # the same as TI normalcdf(-999,-1.5,0,1)
```



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NORMAL DISTRIBUTIONS

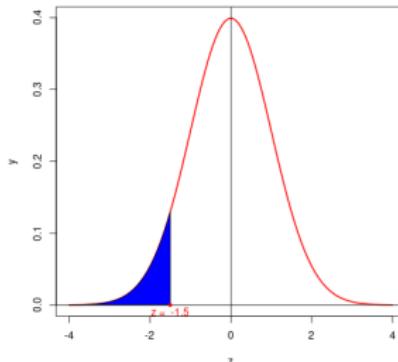
pnorm, qnorm, dnorm

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> pnorm(-1.5) # the same as TI normalcdf(-999,-1.5,0,1)
```

```
[1] 0.0668072
```



NORMAL DISTRIBUTIONS

qnorm

NORMAL DISTRIBUTIONS

qnorm

Q: Find z which solve $.90 = P(z < z)$.

NORMAL DISTRIBUTIONS

qnorm

Q: Find z which solve $.90 = P(z < z)$.

```
> qnorm(.95) # the same as TI invNorm(.95,0,1)
```



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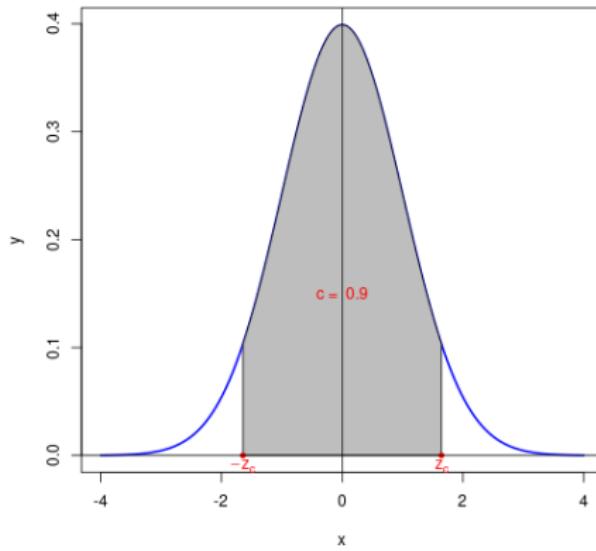
NORMAL DISTRIBUTIONS

qnorm

Q: Find z which solve $.90 = P(z < z)$.

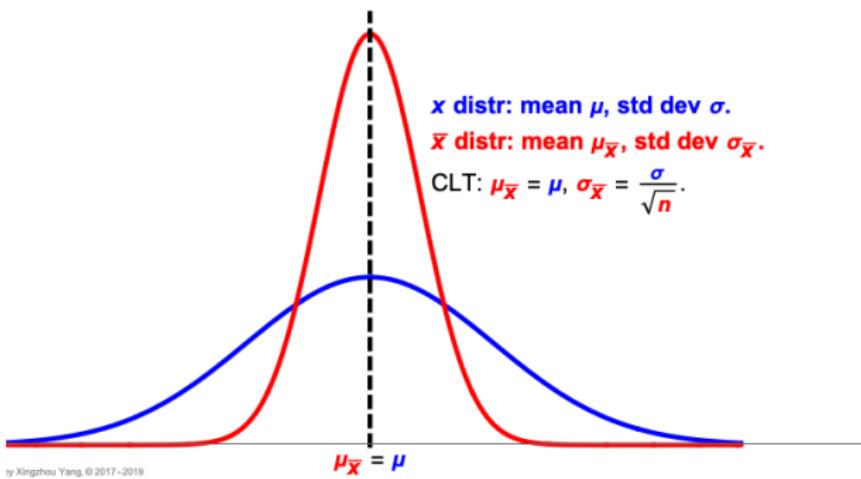
> **qnorm(.95) # the same as TI invNorm(.95,0,1)**

[1] 1.644854



NORMAL DISTRIBUTIONS

Central Limit Theorem



by Xingzhou Yang, © 2017–2018



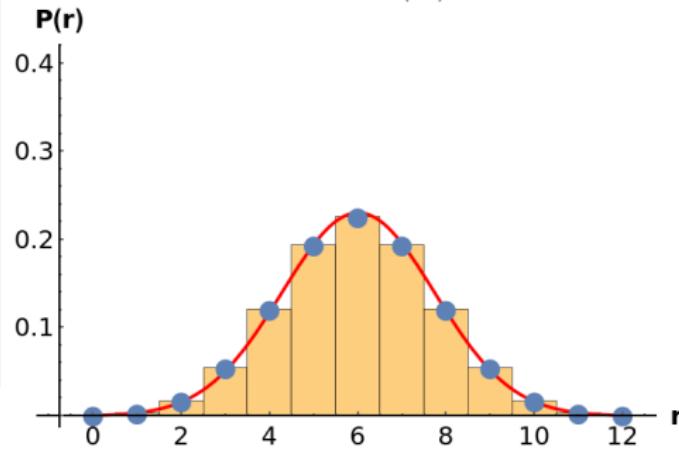
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BINOMIAL DISTRIBUTIONS

X	P(X=r)
0	0.000244
1	0.002930
2	0.016113
3	0.053711
4	0.120850
5	0.193359
6	0.225586
7	0.193359
8	0.120850
9	0.053711
10	0.016113
11	0.002930
12	0.000244

Binomial distribution: $n = 12$, $p = 0.50$

$$P(r) = {}_nC_r \ p^r(1-p)^{n-r} = \frac{n!}{r!(n-r)!} p^r(1-p)^{n-r}$$



by Xingzhou Yang © 2019



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BINOMIAL DISTRIBUTIONS

dbinom & pbinom

- ➊ Probability with **EXACTLY** r successes



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BINOMIAL DISTRIBUTIONS

dbinom & pbinom

- ① Probability with **EXACTLY** r successes

$$P(X = r) = \text{dbinom}(r, n, p) = \text{binompdf}(n, p, r)$$

$$P(X = 1) = \text{TI binompdf}(50, .06, 1)$$



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BINOMIAL DISTRIBUTIONS

dbinom & pbinom

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$P(X = 1) = \text{TI binompdf}(50, .06, 1)$

> **dbinom(1, 50, .06)**

[1] 0.1446725



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BINOMIAL DISTRIBUTIONS

dbinom & pbinom

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$P(X = r) = \text{dbinom}(r, n, p) = \text{binompdf}(n, p, r)$

$P(X = 1) = \text{TI binompdf}(50, .06, 1)$

`> dbinom(1, 50, .06)`

[1] 0.1446725

- ② Probability with **at most (less than or equal to)** r successes:



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BINOMIAL DISTRIBUTIONS

dbinom & pbinom

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$$P(X = r) = \text{dbinom}(r, n, p) = \text{binompdf}(n, p, r)$$

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$$> \text{dbinom}(1, 50, .06)$$

```
[1] 0.1446725
```

- ② Probability with **at most (less than or equal to)** r successes:

$$P(X \leq r) = \text{pbinom}(r, n, p) = \text{binomcdf}(n, p, r)$$

$$P(X \leq 1) = \text{TI binomcdf}(50, .06, 1)$$



BINOMIAL DISTRIBUTIONS

dbinom & pbinom

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> **dbinom(1, 50, .06)**

[1] 0.1446725

- ② Probability with **at most (less than or equal to)** r successes:

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> **pbinom(1, 50, .06)**

[1] 0.1900033



BINOMIAL DISTRIBUTIONS

dbinom & pbinom

- ① Probability with **EXACTLY** r successes

$$P(X = r) = \text{dbinom}(r, n, p) = \text{binompdf}(n, p, r)$$

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```
[1] 0.1446725
```

- ② Probability with **at most (less than or equal to)** r successes:

$$P(X \leq r) = \text{pbinom}(r, n, p) = \text{binomcdf}(n, p, r)$$

$$P(X \leq 1) = \text{TI binomcdf}(50, .06, 1)$$

$$> \text{pbinom}(1, 50, .06)$$

```
[1] 0.1900033
```

③ $P(X > r) = 1 - P(X \leq r)$, $P(X < r) = P(X \leq r - 1)$,

$$P(X \geq r) = 1 - P(X < r) = 1 - P(X \leq r - 1).$$



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PLOT IN R

Histogram of x distribution

PLOT IN R

Histogram of x distribution

```
> x = c(rgamma(5800, 2)) # generate a random population
```

Histogram of x distribution

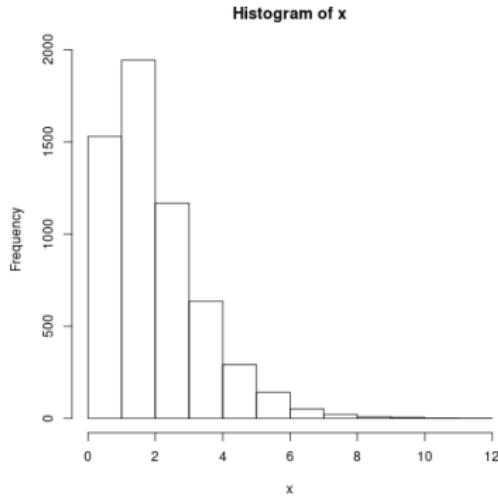
```
> x = c(rgamma(5800, 2)) # generate a random population  
> hist(x) # plot the histogram of x
```



PLOT IN R

Histogram of x distribution

```
> x = c(rgamma(5800, 2)) # generate a random population  
> hist(x) # plot the histogram of x
```



Histogram of the sampling distribution

The R script to generate the sampling distribution from x

Histogram of the sampling distribution

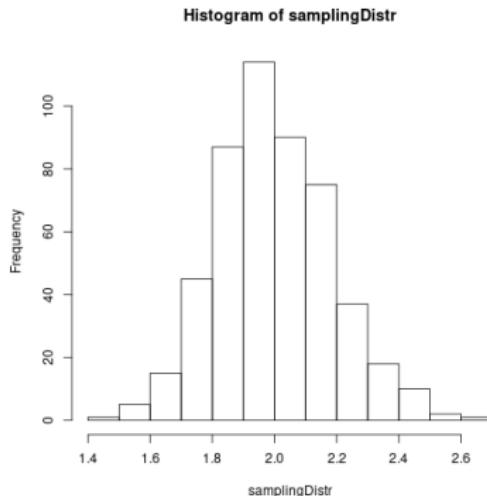
The R script to generate the sampling distribution from x

```
samplingDistr = c() # creates a new empty list
for (i in 1:500) {
    temp = sample(x, 50, replace=F);
    samplingDistr = c(samplingDistr, mean(temp));
}
hist(samplingDistr) # histogram of the sampling distribution
```



PLOT IN R

Histogram of the sampling distribution



SAVE AND LOAD DATA

Save your data

- ① Know where you are:

```
> getwd() # Your current working directory or folder  
[1] "/home/yang" # (my home directory)
```

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```

- ② Find how much you have done – list all your data

```
> ls() # list all the data in your workspace
```

```
[1] "c" "x" "x4" "y" "z" # output
```

```
> rm(c) # remove object "c"
```

```
> ls() # list all the data in your workspace
```

```
[1] "x" "x4" "y" "z" # output
```



SAVE AND LOAD DATA

Save your data

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[1] "/home/yang" # (my home directory)
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```

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> rm(c) # remove object "c"
```

```
> ls() # list all the data in your workspace
```

```
[1] "x" "x4" "y" "z" # output
```

- ③ Save your work to “my-project.RData”

```
> save.image("my-project.RData")
```



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SAVE AND LOAD DATA

Load your data

- ① Check if the file is in your current working directory or folder
 > **system('Is my-project.RData')** # R is case sensitive
 [1] my-project.RData



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SAVE AND LOAD DATA

Load your data

- ① Check if the file is in your current working directory or folder
 > **system('Is my-project.RData')** # R is case sensitive

```
[1] my-project.RData
```

If you partially remember your file name, you can type

```
> system('Is *.RData')
```

If the file is not in your current directory, copy it to here.

- ② If the RData file is in your current directory, then you can load it and continue your work.

```
> ls() # list all the data in your workspace
```

```
[1] character(0) # no objects in your workspace
```

```
> load("my-project.RData") # load your data"
```

```
> ls() # list all the data in your workspace
```

```
[1] "x" "x4" "y" "z" # output
```

Now you may continue your work.



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REFERENCES I



Emmanuel Paradis, R for beginners.



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