conductR: an R program to measure stem, leaf or root hydraulic conductance with an electronic balance or pipette

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last updated Nov 2018 for v.18

(this document is best viewed in full screen / presentation mode)

program available from
https://uwmadison.app.box.com/v/conductR

for troubleshooting help, feedback, or bug reports, contact
ddsmith3@wisc.edu

Outline - how to use the program and potentially useful details

Setting up balance communications

You need

- Balance
  - conductR is coded for Sartorius, Mettler, Ohaus or Scientech balances
  - we use a Sartorius Entris 224-1S with 4-point precision
  - in theory, any balance with a serial port is capable with a few code modifications
- USB cable for balance (note: Sartorius cables (part: YCC01-USBM2) are wired differently from others)
- Driver for cable - may not be necessary for newer operating systems
  - e.g. http://www.ftdichip.com/Drivers/VCP.htm for a Sartorius cable
  - e.g. http://www.prolific.tw for some other cables
- R (https://cran.r-project.org/)
- tcltk (a package that comes with the standard R installation)
- X11 or XQuartz (for Macs only - this runs tcltk; http://www.xquartz.org/)
- R Studio (https://www.rstudio.com/; optional but provides a better interface on *Windows* computers than standard R. Standard R is still needed. RStudio may not work well on a Mac)

Setting up balance communications

Communication settings

- Check that your balance will allow manual printing in unstable conditions.
    - For a Sartorius, e.g. Menu>SETUP>PRNT.OUT>PRINT>MAN.W/O
- Determine port settings. Your balance manual should specify how to find these and change them. Here, I will assume:
    - baud=9600
    - parity=odd
    - data bits=7
    - stop bits=1
    - handshake=software/xonxoff
- Determine port name. This will be COM# in Windows or /dev/cu.usbserial-# on a Mac, where # will vary between ports and computers
    - To find #, turn on the balance and connect it to the computer. For Windows, find # in Device Manager —> Ports. For a Mac, open Terminal (in the Utilities folder) and input: `ls -l /dev/cu.*` For either system, there may be multiple ports so disconnect and reconnect the balance to determine the correct one. If you see no ports, you may need to install driver for cable. On my Mac, #=00001004, which I'll use in the following examples

Setting up balance communications

Try basic communication

- Open R
- Load the tcltk package by typing `require(tcltk)` in the R console.
- Input the following into the R console, replacing the red text with your own port ID (in the first line) and port settings (in the second line):

```
.Tcl('set serial [open /dev/cu.usbserial-00001004 r+]' )
.Tcl('fconfigure $serial -mode \"9600,o,7,1\"  -blocking 0 -handshake xonxoff')
```

- Now press the 'print' button on the balance and then in R input:

```
as.character(.Tcl('return [read $serial]'))
.Tcl('close $serial')
```

- The weight on the balance should appear in R like:

  “+” “62.4317” “g” (typical for Sartorius)

  “S” “D” “62.4317” “g” (typical for Mettler)

- If nothing appears or garbage appears, check port settings (see also Appendix F)
- If sensible numbers appear with a different format see Appendix B

Setting up balance communications

Let the program tell the balance to print

- We need a print command which is Esc-P-CR-LF for Sartorius balances (CR=carriage return and LF=line feed). In the proper format, this command is `\x1B\x50\xD\xA` (see http://www.asciitable.com/). Other commands are:
  - Mettler: S-I-CR-LF (`\x53\x49\xD\xA`)
  - Ohaus: I-P (`\x49\x50`)*
  - Scientech: S-E-N-D-CR-LF (`\x53\x45\x4E\x44\xD\xA`)**
- Now, run the following lines in R - replacing the red text with your port ID (line 1), port settings (line 2), and print code (line 3):

```
.Tcl('set serial [open /dev/cu.usbserial-00001004 r+]' )
.Tcl('fconfigure $serial -mode \"9600,o,7,1\"  -blocking 0 -handshake xonxoff')
.Tcl('puts $serial \x1B\x50\xD\xA')
.Tcl('flush $serial')
Sys.sleep(0.1)
.Tcl('return [read $serial]')
.Tcl('close $serial')
```

*thanks Stephanie Schmiege

**thanks Greg Vose

Setting up balance communications

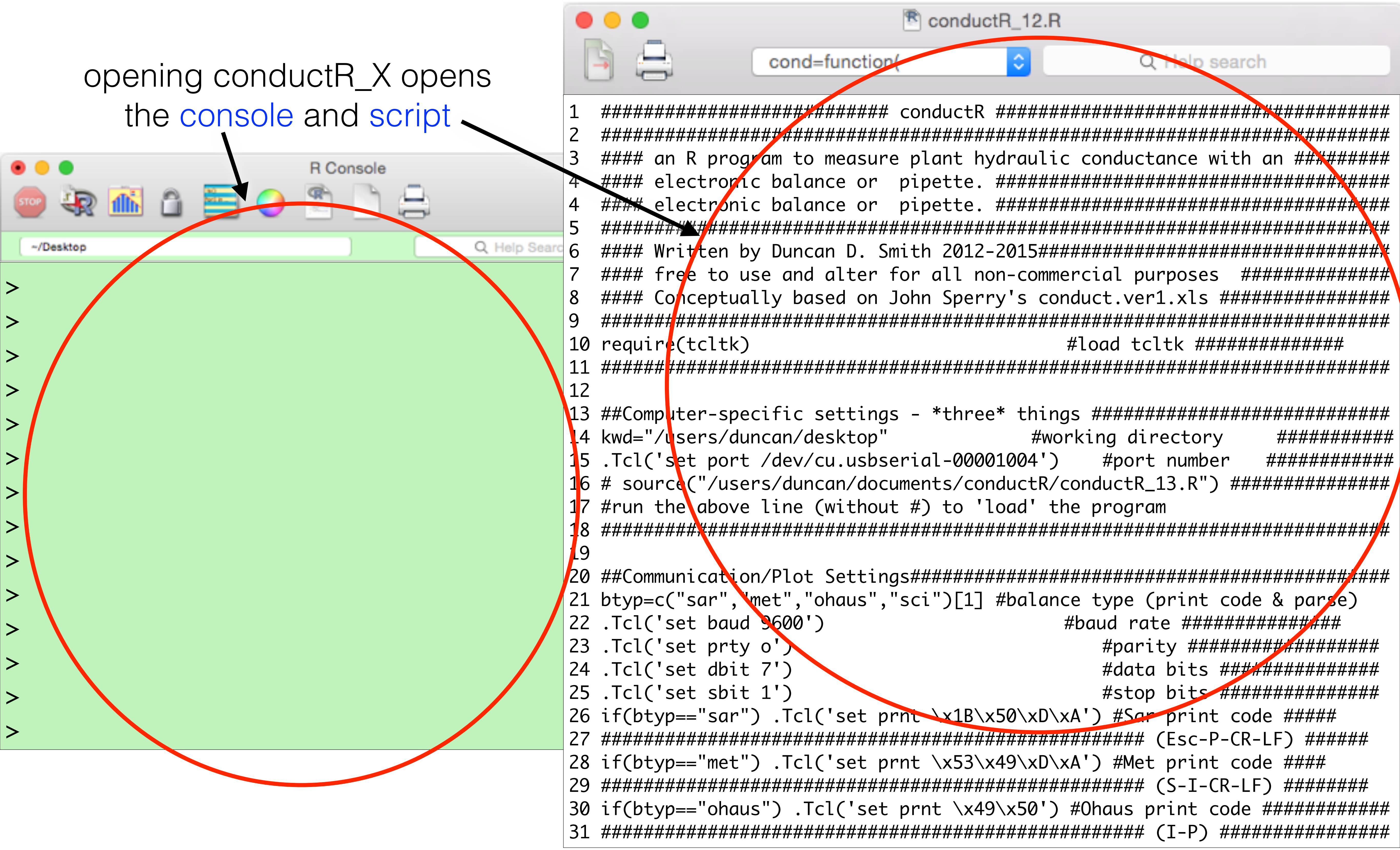
Let the program tell the balance to print (continued)

- R should return the weight on the balance. Note that the flush command forces the print command to send and Sys.sleep(0.1) waits 0.1 s, which should be long enough for a response. If it does not work, I would try a simpler command like ‘tare’ (Esc-T-CR-LF = \x1B\x54\xD\xA for Sartorius) because it will be clear whether the balance received the command or not (i.e. the balance should tare). You might also increase the Sys.sleep() time.

Now to use the program

Initial setup

opening conductR_X opens the console and script



Initial setup

R Console

~/Desktop

Help Searc

>
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>

set the:
working directory*
port number
and the location of the conductR file

Do these whenever setting up a new computer or version

conductR_12.R

cond=function(

Help search

```
6  #### Written by Duncan D. Smith 2012-2015#################################
7  #### free to use and alter for all non-commercial purposes  ##############
8  #### Conceptually based on John Sperry's conduct.ver1.xls ################
9  ########################################################################
10 require(tcltk)                                  #load tcltk ##################
11 ########################################################################
12
13 ##Computer-specific settings - *three* things ############################
14 kwd="/users/duncan/desktop"                #working directory     ###########
15 .Tcl('set port /dev/cu.usbserial-00001004')    #port number    ############
16 # source("/users/duncan/documents/conductR/conductR_13.R") ###############
17 #run the above line (without #) to 'load' the program
18 ########################################################################
19
20 ##Communication/Plot Settings#############################################
21 btyp=c("sar","met","ohaus","sci")[1] #balance type (print code & parse)###
22 .Tcl('set baud 9600')                          #baud rate ################## 
23 .Tcl('set prty o')                              #parity ##################
24 .Tcl('set dbit 7')                              #data bits ###############
25 .Tcl('set sbit 1')                              #stop bits ###############
26 if(btyp=="sar") .Tcl('set prnt \x1B\x50\xD\xA') #Sar print code ##########
27 ################################################## (Esc-P-CR-LF) ########
28 if(btyp=="met") .Tcl('set prnt \x53\x49\xD\xA') #Met print code ##########
29 ################################################## (S-I-CR-LF) ##########
30 if(btyp=="ohaus") .Tcl('set prnt \x49\x50') #Ohaus print code ############
31 ################################################## (I-P) ################
32 if(btyp=="sci") .Tcl('set prnt \x53\x45\x4E\x44\xD\xA') #Scientech code ########
33 ################################################ (S-E-N-D-CR-LF) ############
34 par(mar=c(5,5,1,1))                             #plot margins etc ############
35 ########################################################################
36
37 ##Location Settings#######################################################
```

*if you are new to R, type **`getwd()`** into the console to see your current working directory. Then work out what directory you want files to be saved in.

Initial setup

R Console

~/Desktop

Help Searc

>
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>
>

choose balance type
1=Sartorius,
2=Mettler
3=Ohaus
4=Scientech*

change port settings

and plot settings
(if any)

conductR_12.R

cond=function(

Help search

```
6  #### Written by Duncan D. Smith 2012-2015#################################
7  #### free to use and alter for all non-commercial purposes  ##############
8  #### Conceptually based on John Sperry's conduct.ver1.xls ################
9  ########################################################################
10 require(tcltk)                                  #load tcltk ##################
11 ########################################################################
12
13 ##Computer-specific settings - *three* things ############################
14 kwd="/users/duncan/desktop"                #working directory     ###########
15 .Tcl('set port /dev/cu.usbserial-00001004')    #port number    ############
16 # source("/users/duncan/documents/conductR/conductR_13.R") ###############
17 #run the above line (without #) to 'load' the program
18 ########################################################################
19
20 ##Communication/Plot Settings#############################################
21 btyp=c("sar","met","ohaus","sci")[1] #balance type (print code & parse)###
22 .Tcl('set baud 9600')                          #baud rate ##################
23 .Tcl('set prty o')                               #parity ##################
24 .Tcl('set dbit 7')                               #data bits ###############
25 .Tcl('set sbit 1')                               #stop bits ###############
26 if(btyp=="sar") .Tcl('set prnt \x1B\x50\xD\xA') #Sar print code ##########
27 ################################################ (Esc-P-CR-LF) ########
28 if(btyp=="met") .Tcl('set prnt \x53\x49\xD\xA') #Met print code ##########
29 ################################################ (S-I-CR-LF) ##########
30 if(btyp=="ohaus") .Tcl('set prnt \x49\x50') #Ohaus print code ############
31 ################################################ (I-P) ################
32 if(btyp=="sci") .Tcl('set prnt \x53\x45\x4E\x44\xD\xA') #Scientech code ########
33 ############################################## (S-E-N-D-CR-LF) ############
34 par(mar=c(5,5,1,1))                           #plot margins etc ############
35 ########################################################################
36
37 ##Location Settings#######################################################
```

*Balance type determines print code (see lines 26, 28, 30, 32) and how to extract numbers from what balance prints (see **decod()** function in Appendices A & B)

Initial setup

R Console

~/Desktop

```
>
>
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>
>
>
>
>
>
```

check location settings (used to determine gravity)

conductR_12.R

cond=function(

Help search

```
8  #### Conceptually based on John Sperry's conduct.ver1.xls ###############
9  ########################################################################
10 require(tcltk)                                  #load tcltk ##############
11 ########################################################################
12
13 ##Computer-specific settings - *three* things ############################
14 kwd="/users/duncan/desktop"                #working directory     ##########
15 .Tcl('set port /dev/cu.usbserial-00001004')    #port number    ##########
16 # source("/users/duncan/documents/conductR/conductR_13.R") ##############
17 #run the above line (without #) to 'load' the program
18 ########################################################################
19
20 ##Communication/Plot Settings#############################################
21 btyp=c("sar","met","ohaus","sci")[1] #balance type (print code & parse)###
22 .Tcl('set baud 9600')                          #baud rate ##############
23 .Tcl('set prty o')                              #parity ##############
24 .Tcl('set dbit 7')                              #data bits ##############
25 .Tcl('set sbit 1')                              #stop bits ##############
26 if(btyp=="sar") .Tcl('set prnt \x1B\x50\xD\xA') #Sar print code ##########
27 ################################################## (Esc-P-CR-LF) ########
28 if(btyp=="met") .Tcl('set prnt \x53\x49\xD\xA') #Met print code ##########
29 ################################################## (S-I-CR-LF) ##########
30 if(btyp=="ohaus") .Tcl('set prnt \x49\x50') #Ohaus print code ############
31 ################################################## (I-P) ################
32 if(btyp=="sci") .Tcl('set prnt \x53\x45\x4E\x44\xD\xA') #Scientech code ########
33 ################################################## (S-E-N-D-CR-LF) ############
34 par(mar=c(5,5,1,1))                            #plot margins etc ############
35 ########################################################################
36
37 ##Location Settings#######################################################
37 elev=280       #elevation (masl)           ##############################
38 lat=43         #latitude (deg)             ##############################
```

Initial setup

R Console

~/Desktop

Help Searc

>
>
>
>
>
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>
>
>
>
>
>
>

save the script if changes were made

conductR_12.R

cond=function(

Help search

```
8  #### Conceptually based on John Sperry's conduct.ver1.xls ###############
9  ########################################################################
10 require(tcltk)                                  #load tcltk ##############
11 ########################################################################
12
13 ##Computer-specific settings - *three* things ############################
14 kwd="/users/duncan/desktop"                #working directory     ##########
15 .Tcl('set port /dev/cu.usbserial-00001004')    #port number    ##########
16 # source("/users/duncan/documents/conductR/conductR_13.R") ##############
17 #run the above line (without #) to 'load' the program
18 ########################################################################
19
20 ##Communication/Plot Settings#############################################
21 btyp=c("sar","met","ohaus","sci")[1] #balance type (print code & parse)###
22 .Tcl('set baud 9600')                          #baud rate ##############
23 .Tcl('set prty o')                              #parity ##############
24 .Tcl('set dbit 7')                              #data bits ##############
25 .Tcl('set sbit 1')                              #stop bits ##############
26 if(btyp=="sar") .Tcl('set prnt \x1B\x50\xD\xA') #Sar print code ##########
27 ################################################## (Esc-P-CR-LF) ########
28 if(btyp=="met") .Tcl('set prnt \x53\x49\xD\xA') #Met print code ##########
29 ################################################## (S-I-CR-LF) ##########
30 if(btyp=="ohaus") .Tcl('set prnt \x49\x50') #Ohaus print code ############
31 ################################################## (I-P) ################
32 if(btyp=="sci") .Tcl('set prnt \x53\x45\x4E\x44\xD\xA') #Scientech code ########
33 ################################################## (S-E-N-D-CR-LF) ############
34 par(mar=c(5,5,1,1))                             #plot margins etc ############
35 ########################################################################
36
37 ##Location Settings#######################################################
37 elev=280       #elevation (masl)           ##############################
38 lat=43         #latitude (deg)             ##############################
```

Initiating the program

R Console

~/Desktop

Help Search

```
>
>
>
>
>
>
>
>
>
>
>
> source("/users/duncan/documents/conductR/conductR_18.R")
```

"load" the script by copying the **source** command into the console

(you can close the script,now)

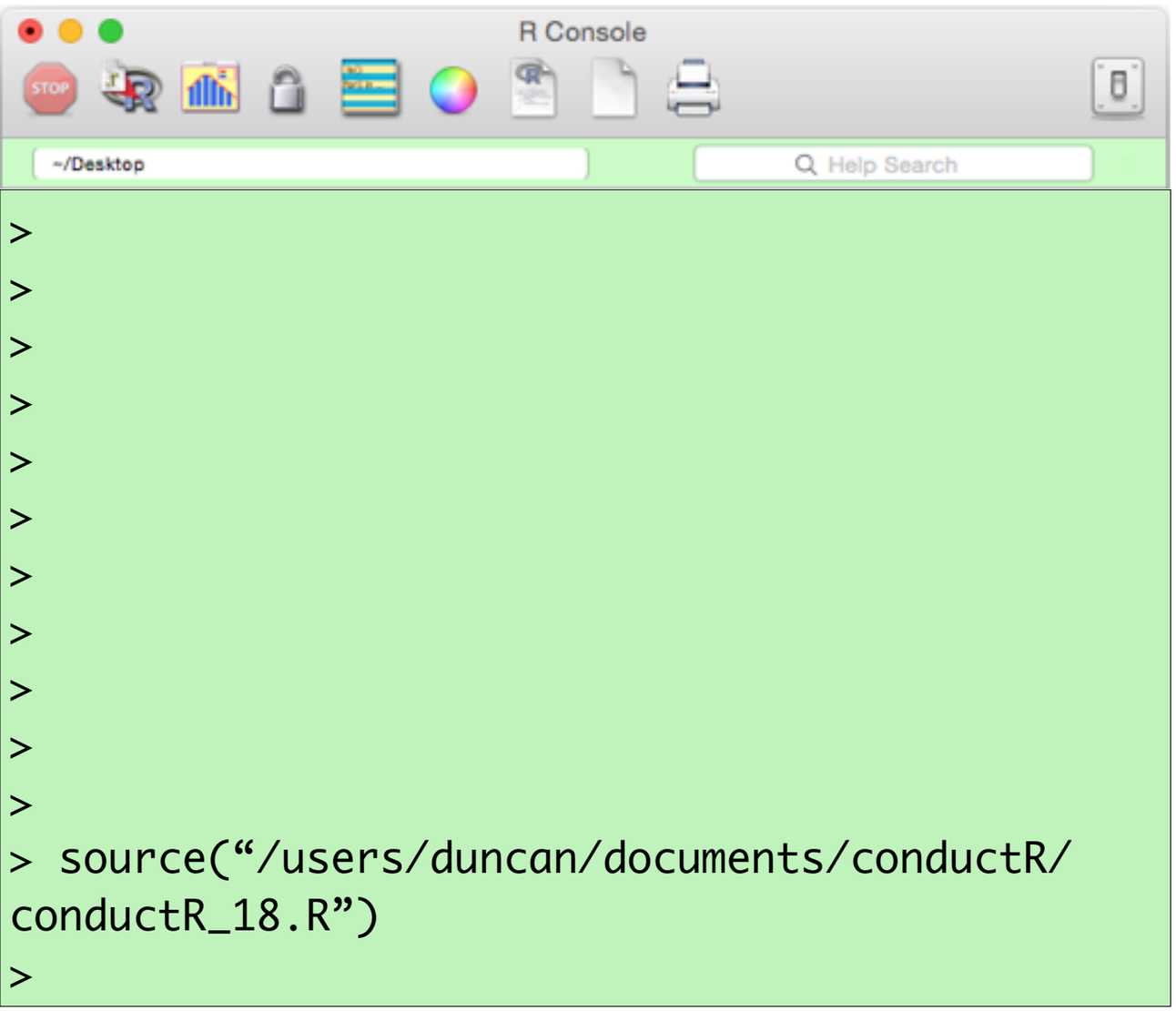
conductR_12.R

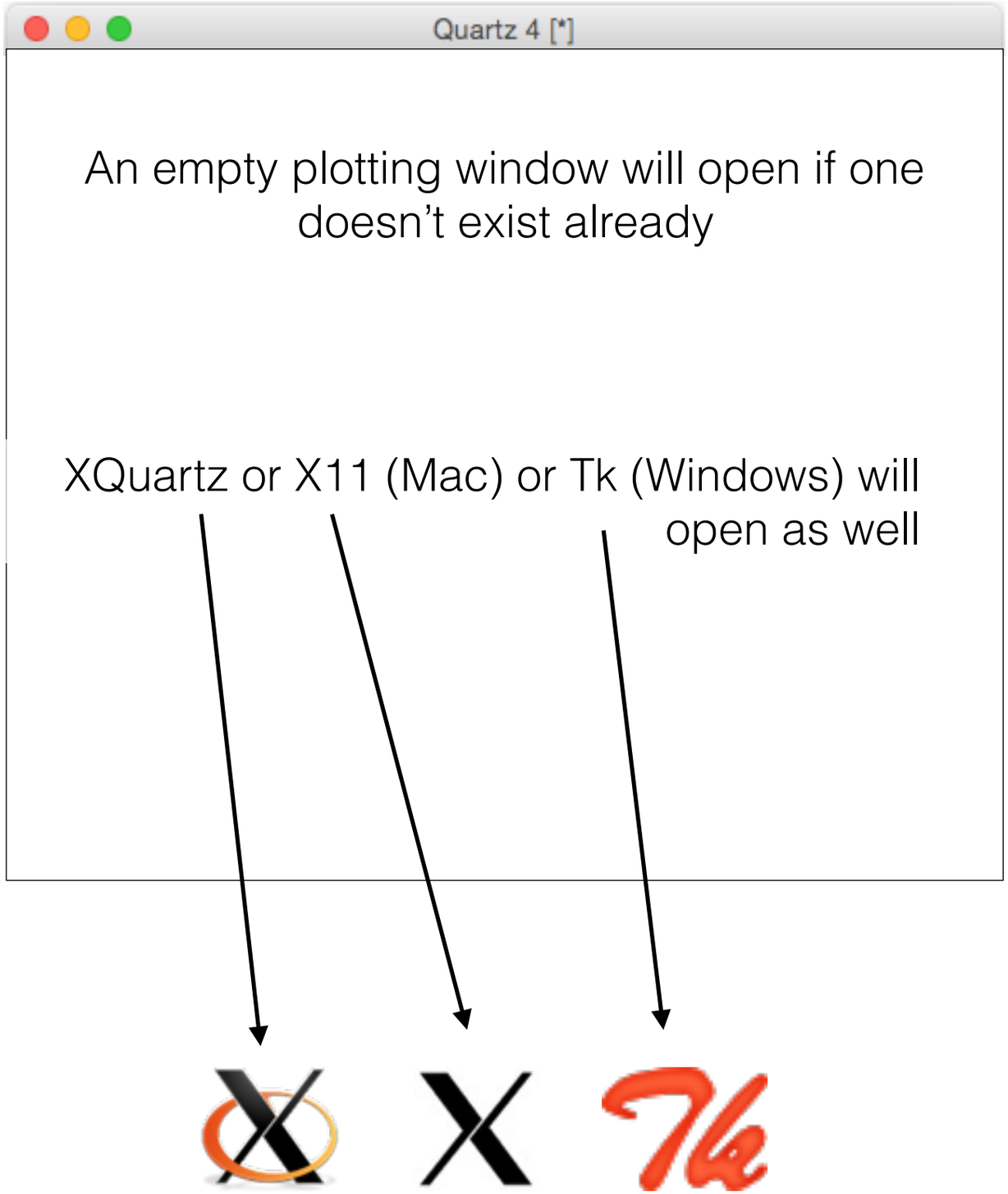
cond=function(

Help sea

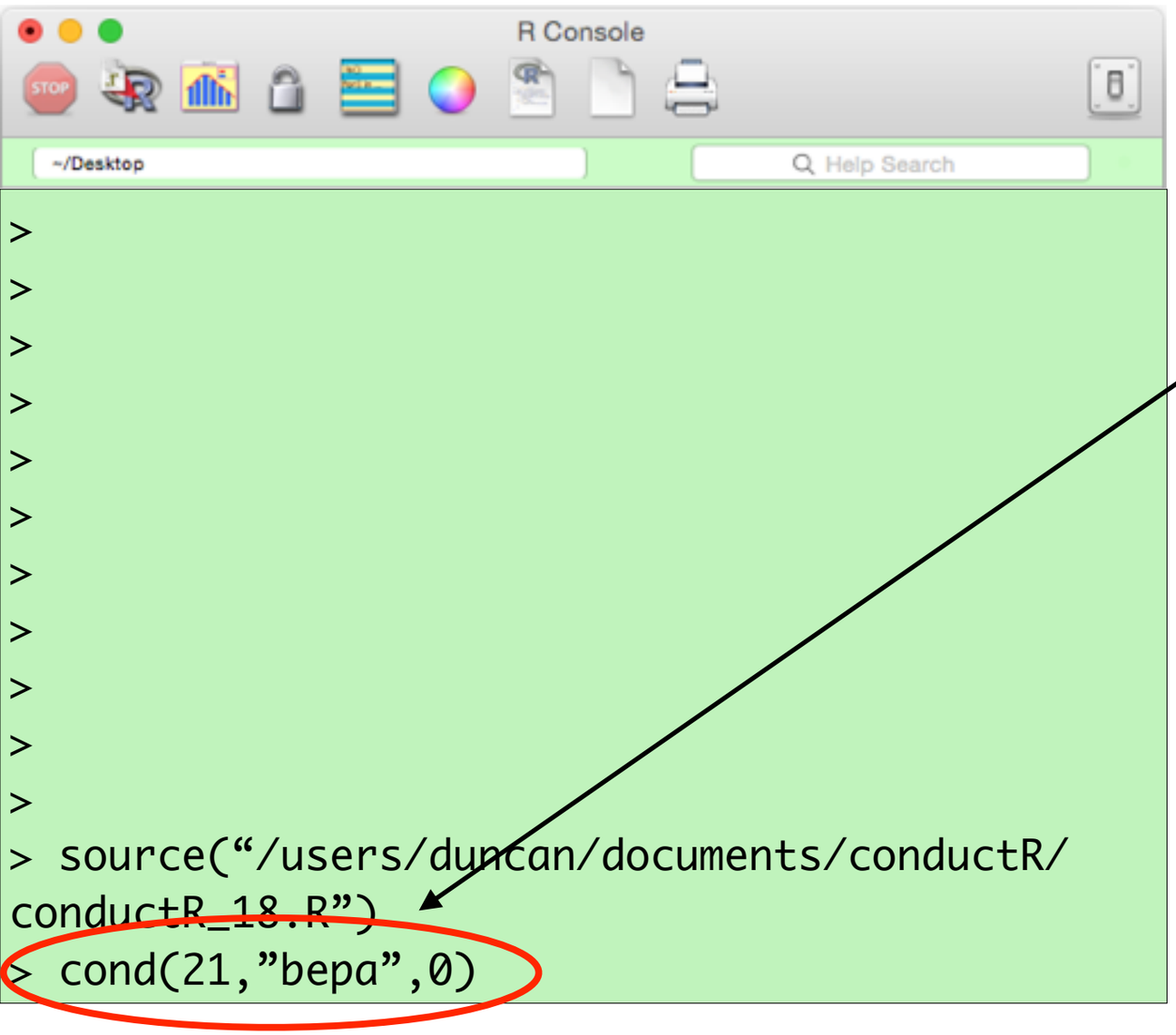
```
8  #### Conceptually based on John Sperry's conduct.ver1.xls ##
9  ###############################################################
10 require(tcltk)                                  #load tcltk ####
11 ###############################################################
12
13 ##Computer-specific settings - *three* things ##############
14 kwd="/users/duncan/desktop"                 #working directory
15 .Tcl('set port /dev/cu.usbserial-00001004')    #port number
16 # source("/users/duncan/documents/conductR/conductR_13.R") #
17 #run the above line (without #) to 'load' the program
18 ###############################################################
19
20 ##Communication/Plot Settings#################################
21 btyp=c("sar","met","ohaus","sci")[1] #balance type (print co
22 .Tcl('set baud 9600')                          #baud rate #####
23 .Tcl('set prty o')                               #parity #####
24 .Tcl('set dbit 7')                               #data bits ##
25 .Tcl('set sbit 1')                               #stop bits ##
26 if(btyp=="sar") .Tcl('set prnt \x1B\x50\xD\xA') #Sar print c
27 ################################################## (Esc-P-C
28 if(btyp=="met") .Tcl('set prnt \x53\x49\xD\xA') #Met print c
29 ################################################## (S-I-CR-
30 if(btyp=="ohaus") .Tcl('set prnt \x49\x50') #Ohaus print cod
31 ################################################## (I-P) ##
32 if(btyp=="sci") .Tcl('set prnt \x53\x45\x4E\x44\xD\xA') #Scientech
33 ################################################## (S-E-N-D-CR-LF
34 par(mar=c(5,5,1,1))                           #plot margins etc
35 ###############################################################
36
37 ##Location Settings###########################################
37 elev=280       #elevation (masl)           ##################
38 lat=43         #latitude (deg)             ##################
```

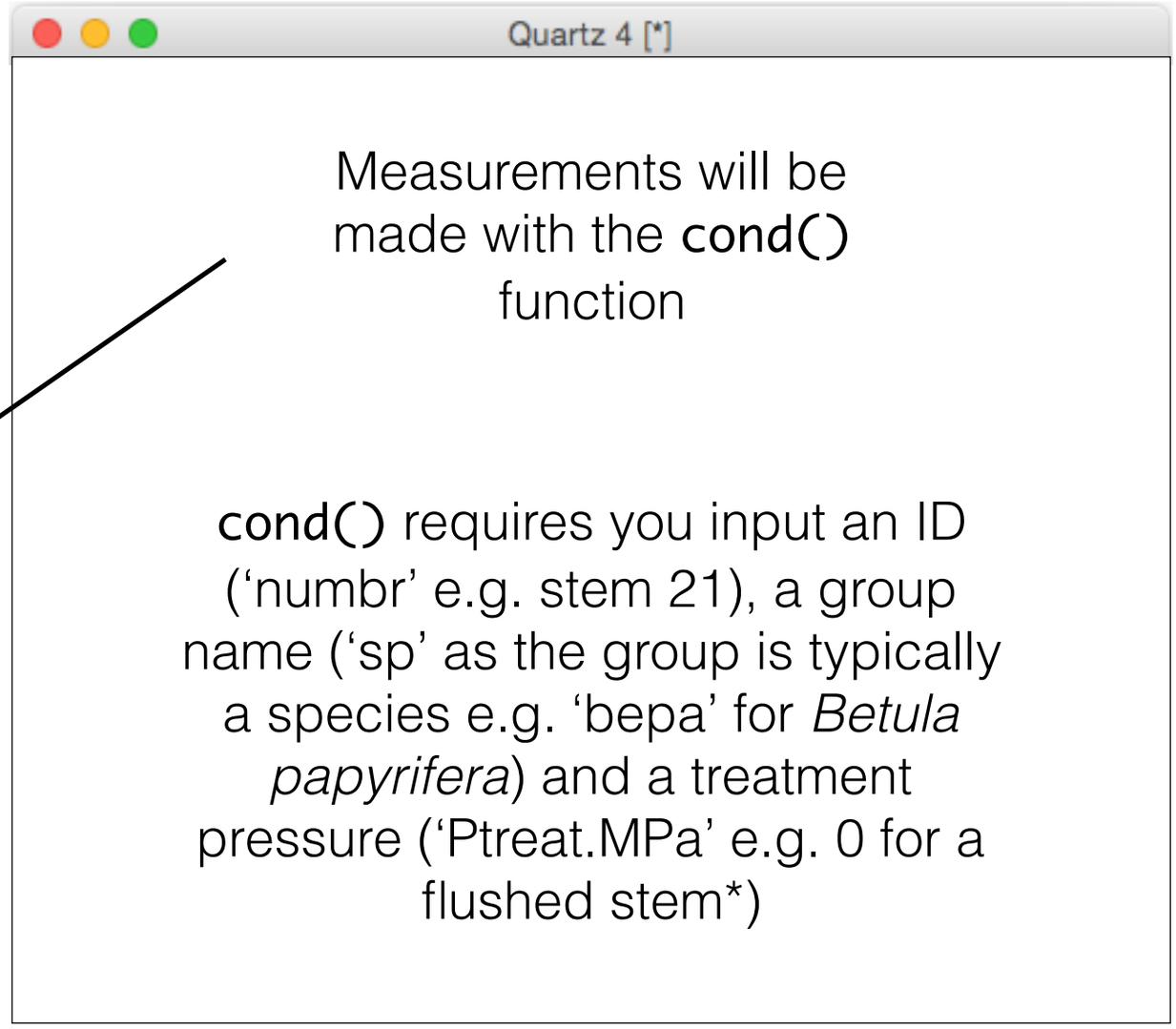
Initiating the program





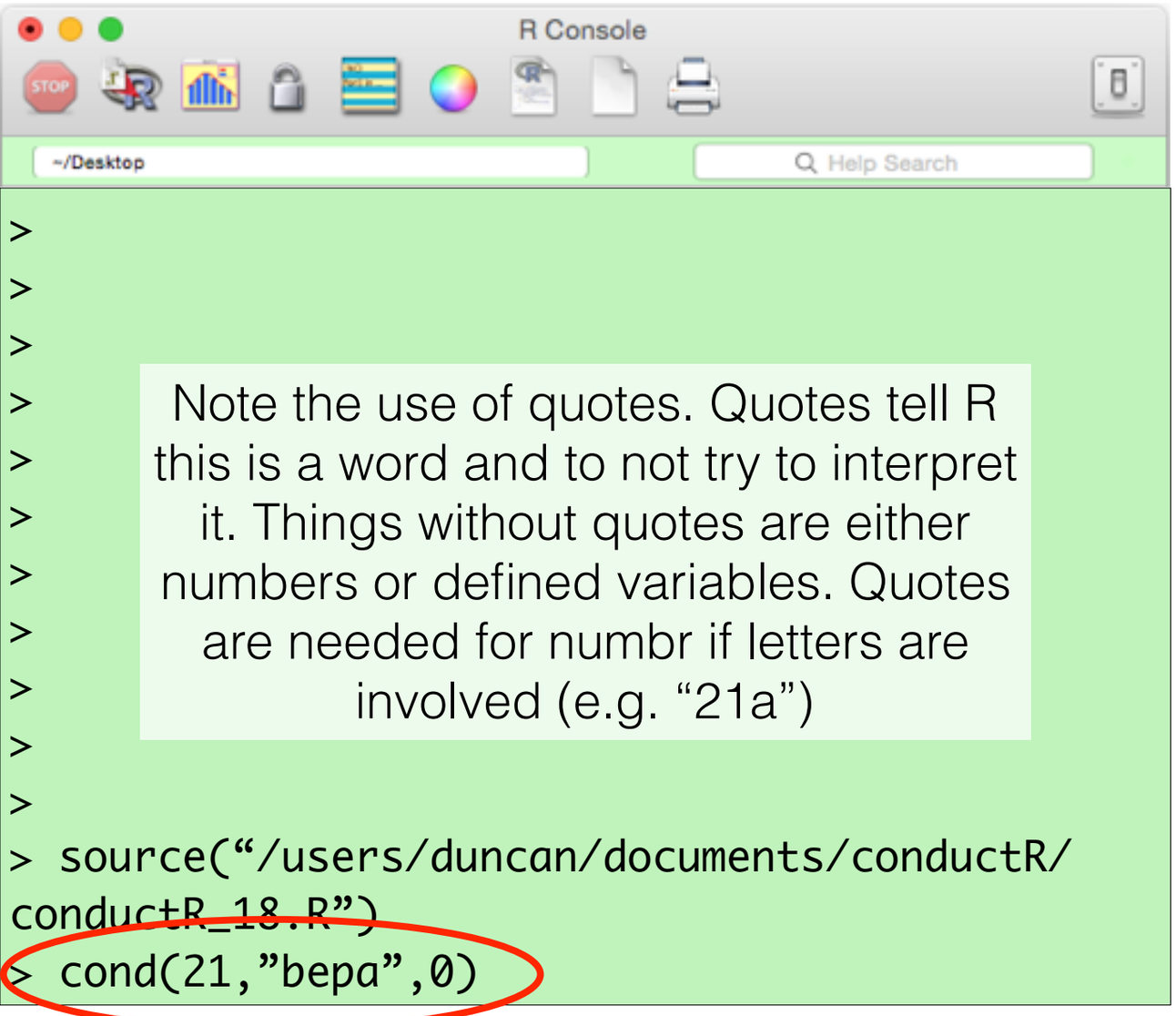
Making measurements with a balance

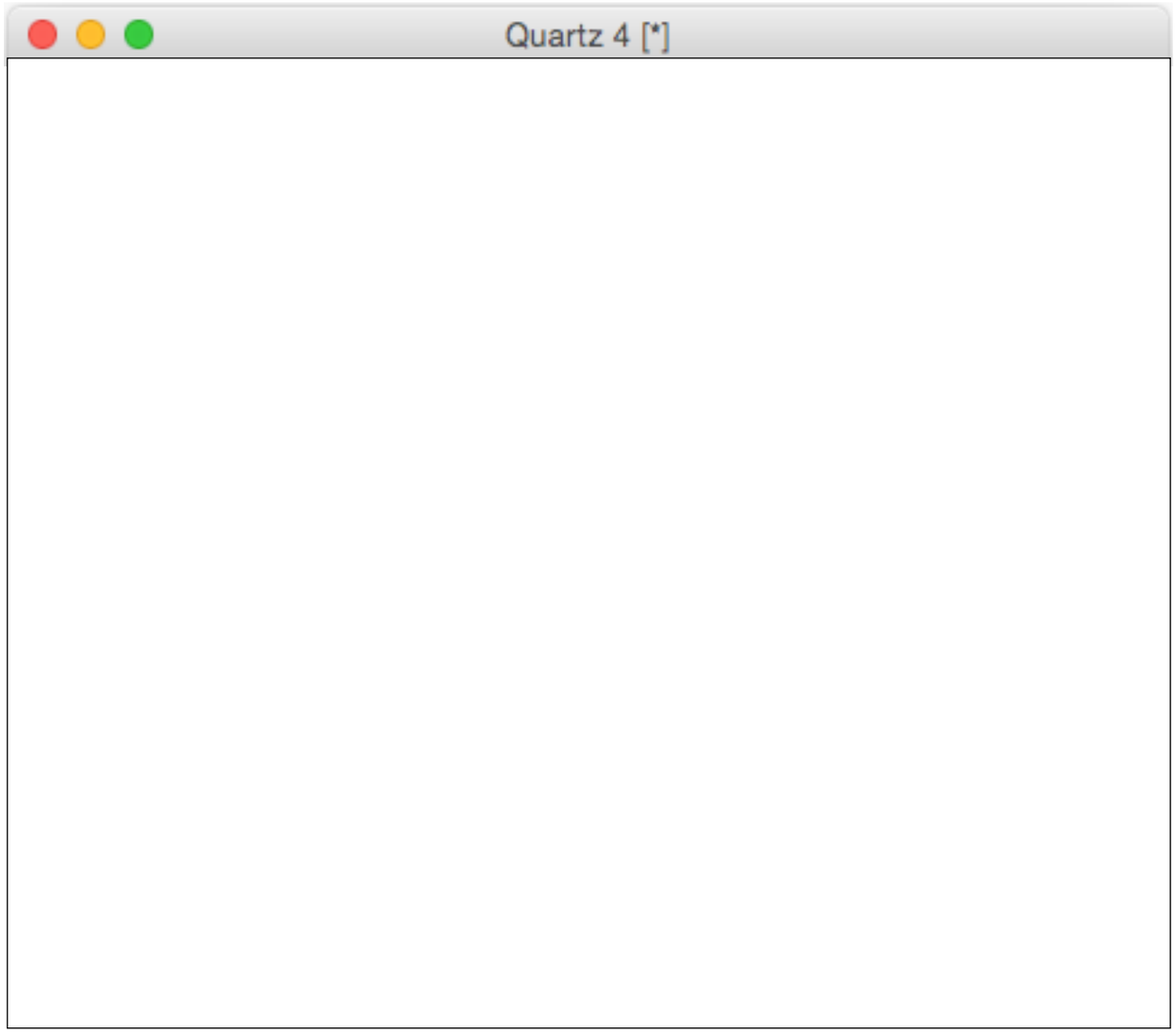




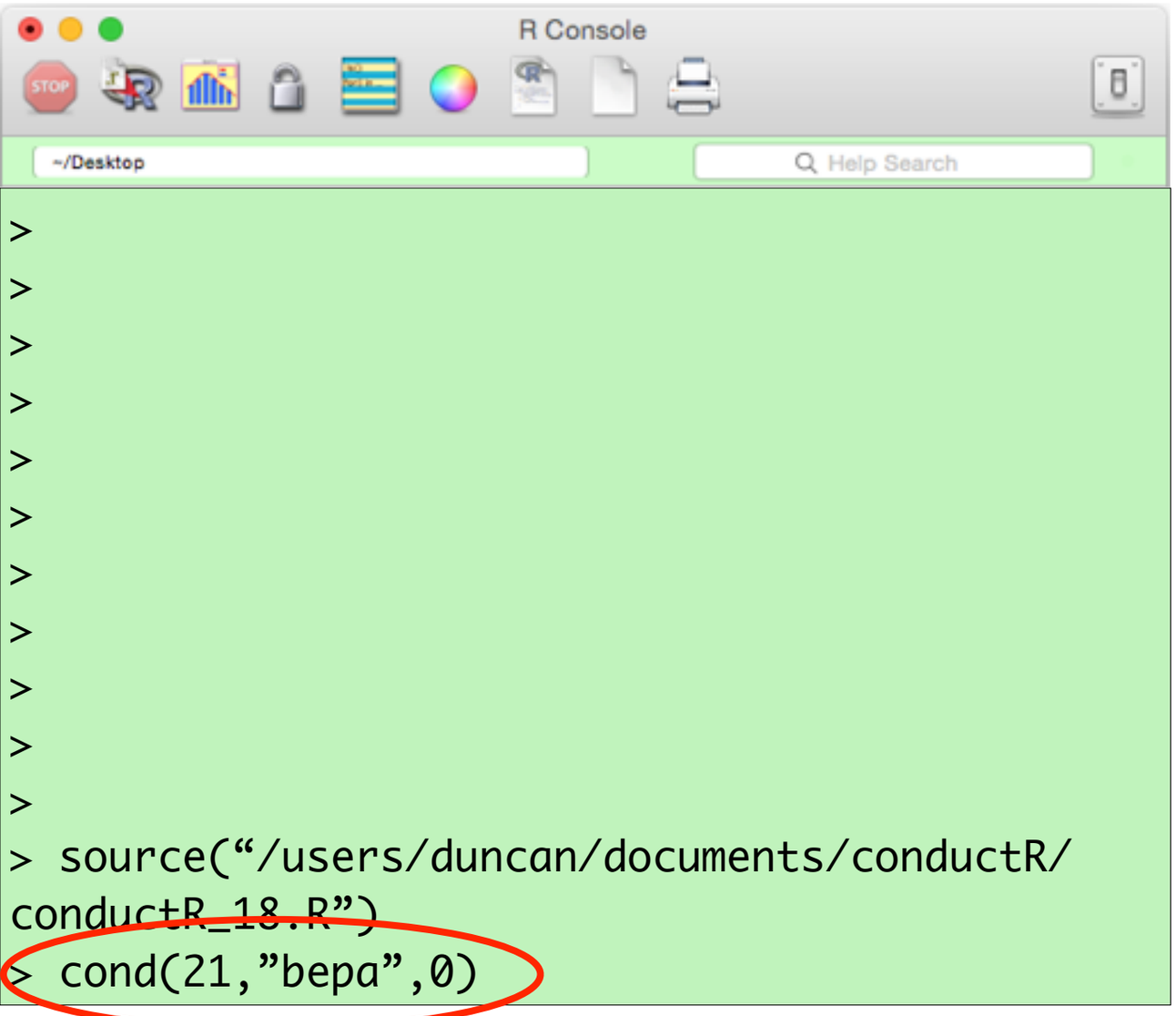
*If measuring native conductance and you didn't measure native xylem pressure, choose some identifying number for Ptreat.MPa (e.g. 999). The program needs a number because it will always try to calculate PLC relative to the most favorable pressure.

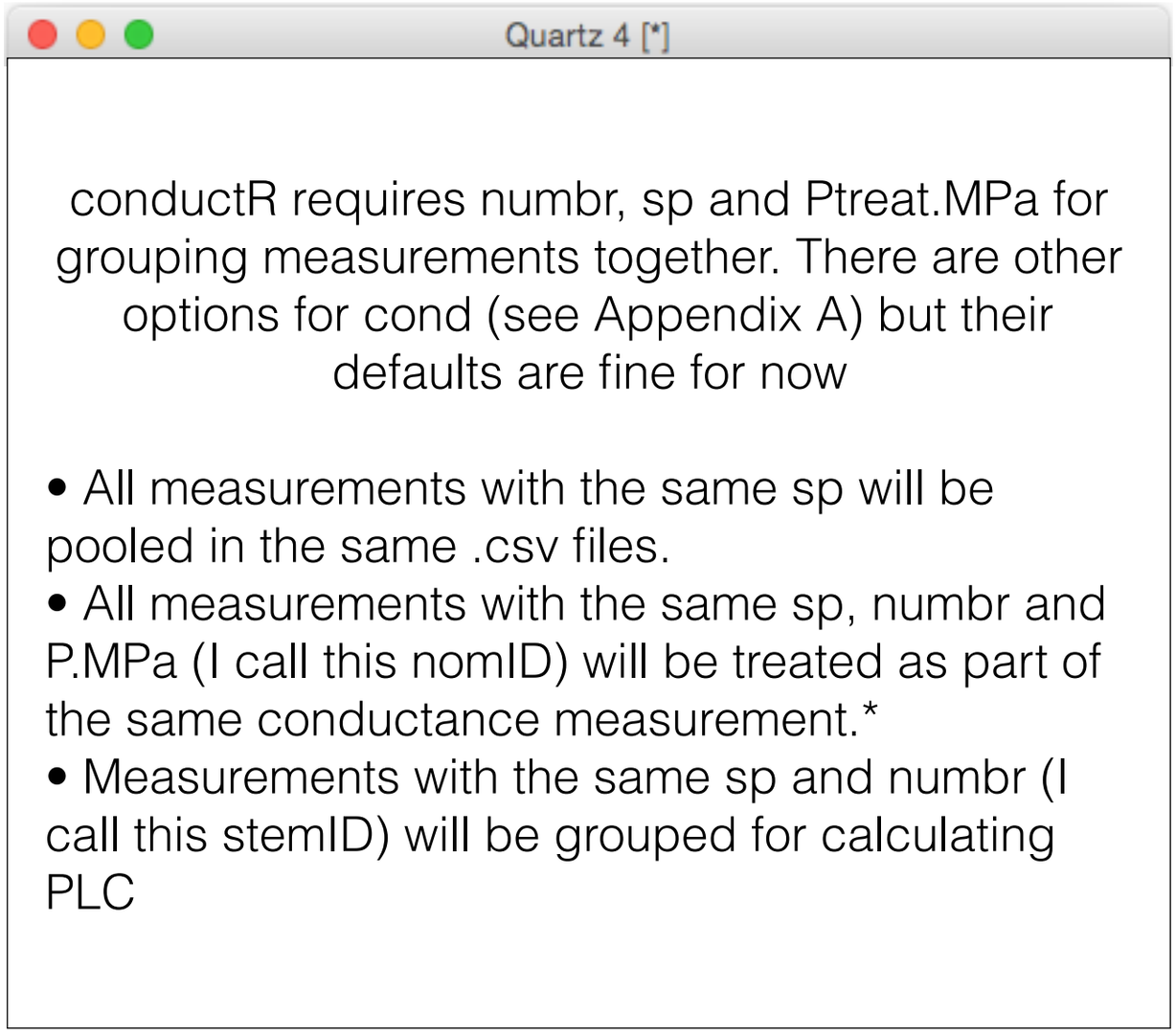
Making measurements with a balance





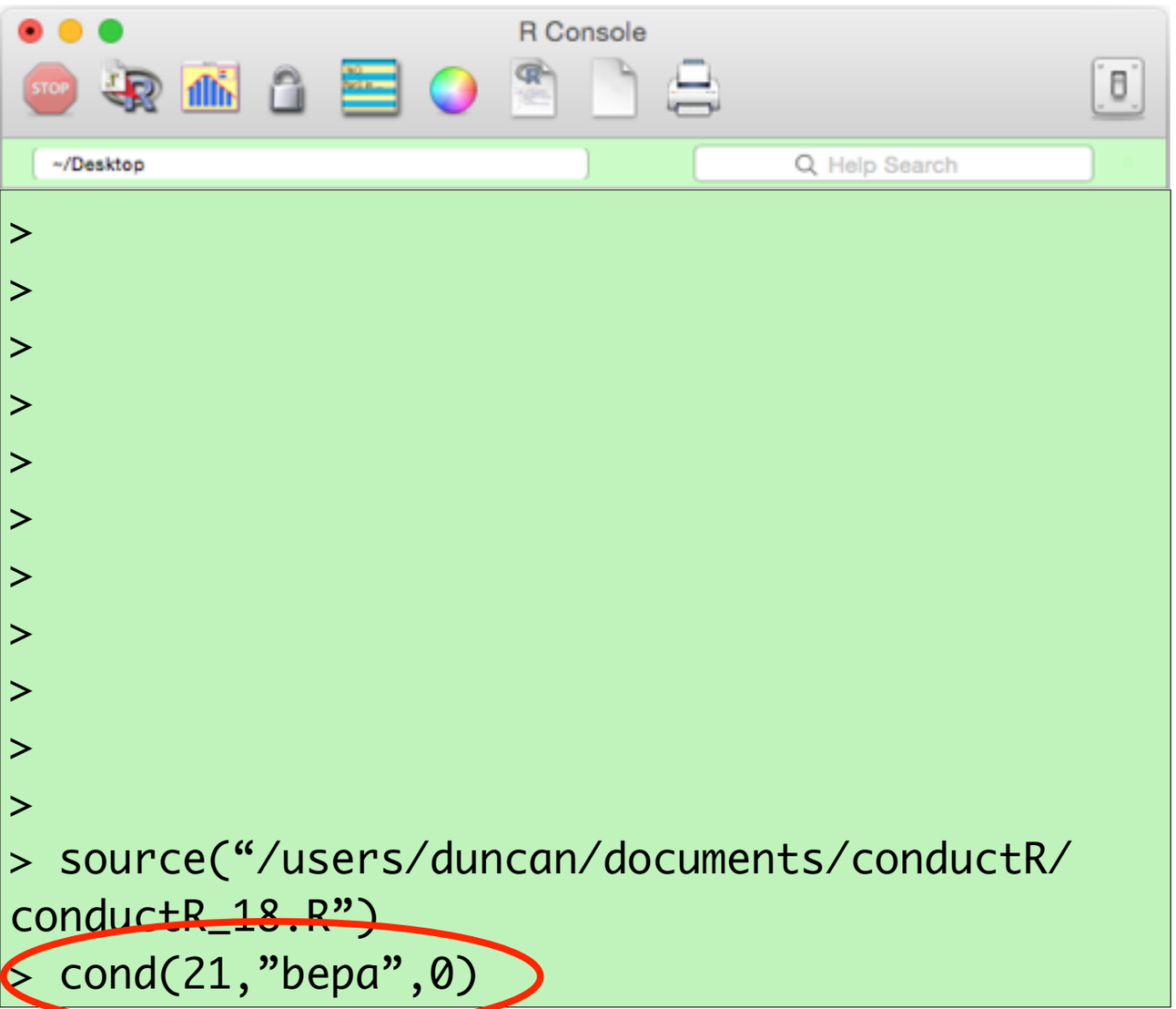
Making measurements with a balance





*To the advanced user: a caveat is if you measure a stem more than once at the same treatment pressure, the program will try to group everything into a single conductance measurement. As a solution, you could: 1) exclude points from earlier measurements when prompted 2) use different names (e.g. 21.1, 21.2, 21.3) or 3) input slightly different pressures (e.g. 2.0, 2.00001, 2.00002). I favor option 3.

Making measurements with a balance

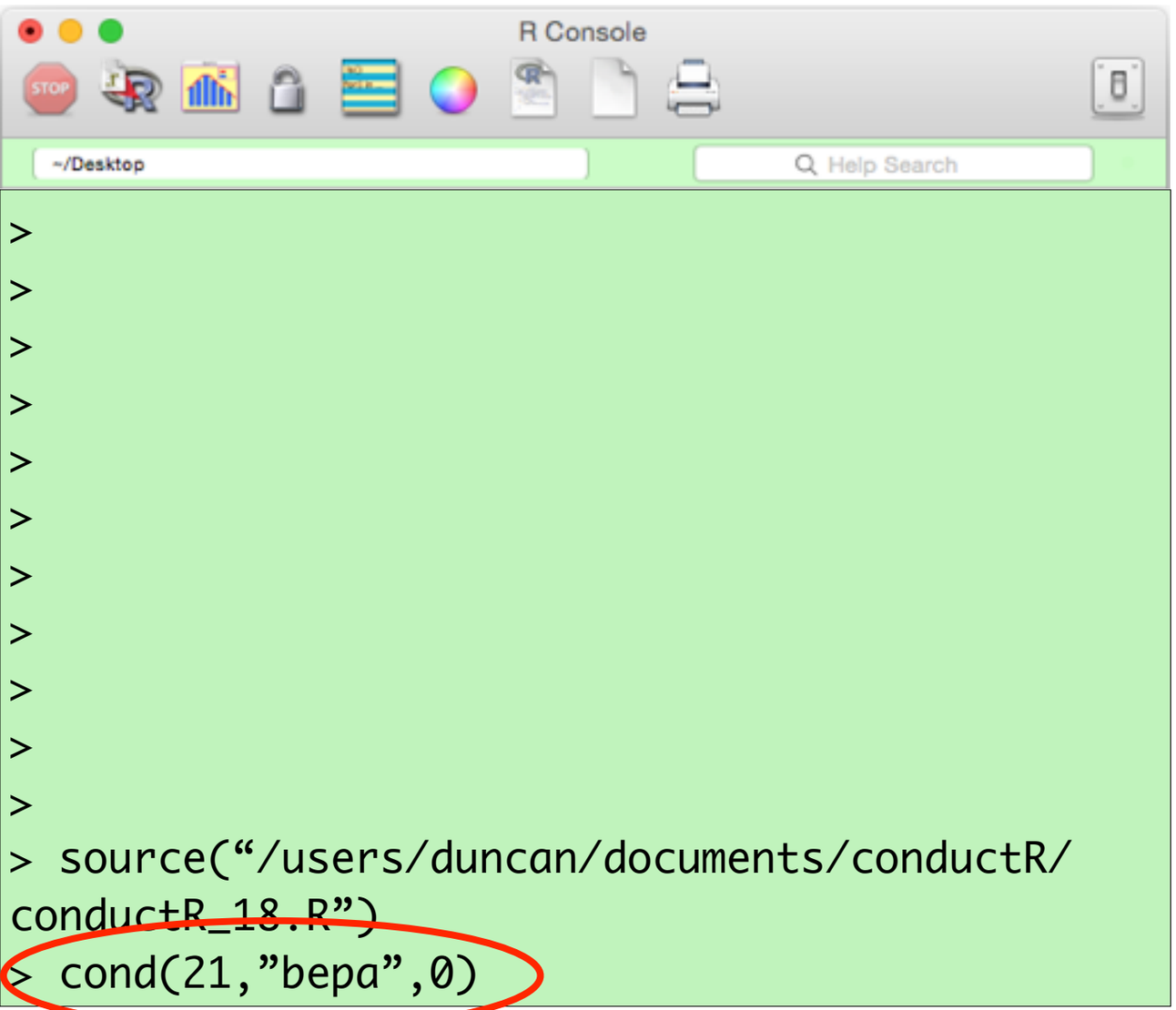


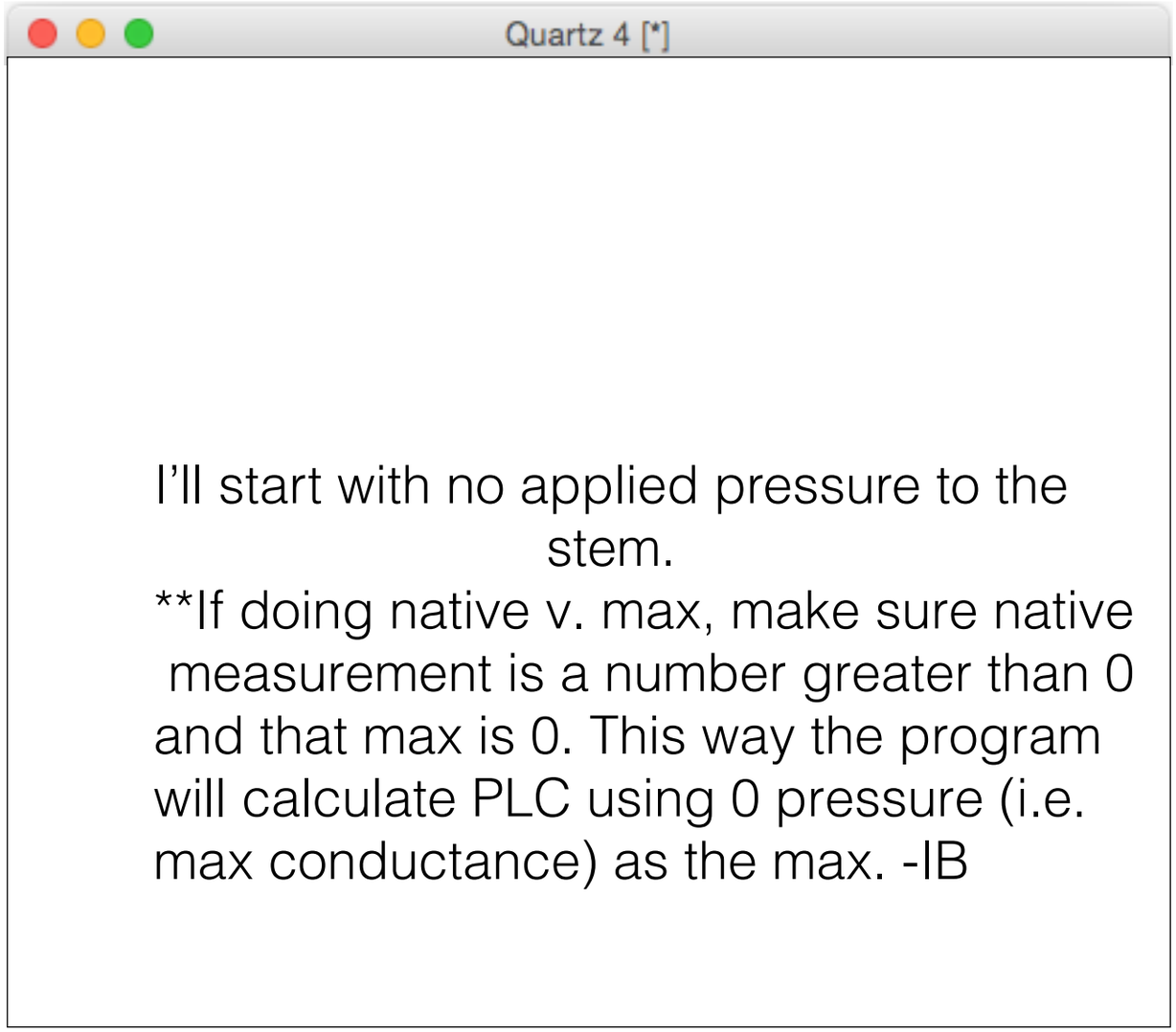
Quartz 4 [*]

You can follow along in R and make your own conductance measurement. For an illustrated guide to measuring hydraulic conductance see https://uwmadison.app.box.com/v/conductR 'conductance protocol v2.pdf'

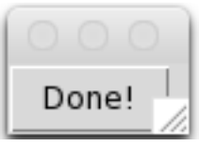
You can alternatively make a pretend measurement without being connected to a balance by adding testmode=T to all the cond commands e.g.
`cond(21,"bepa",0,testmode=T)`

Making measurements with a balance

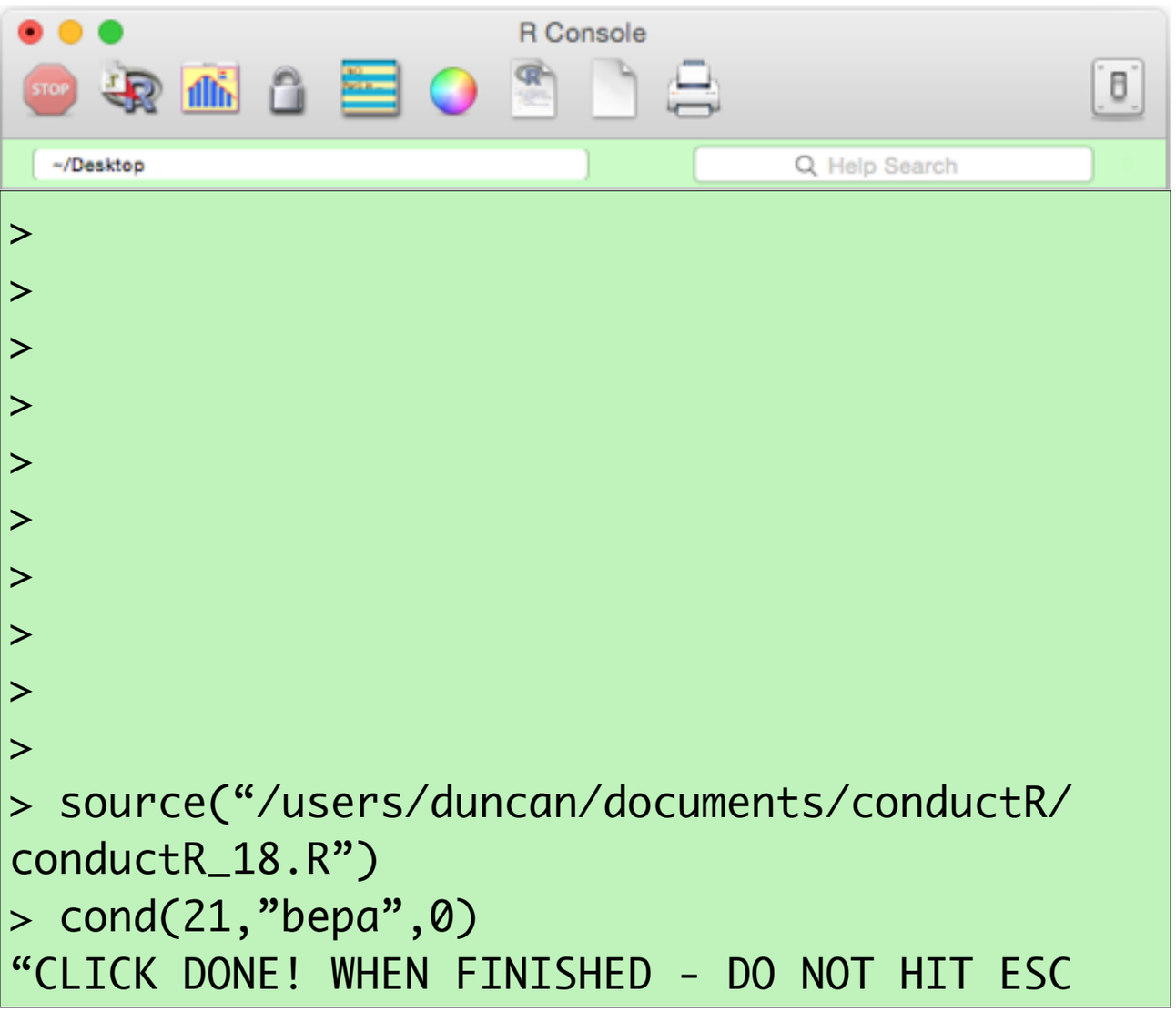


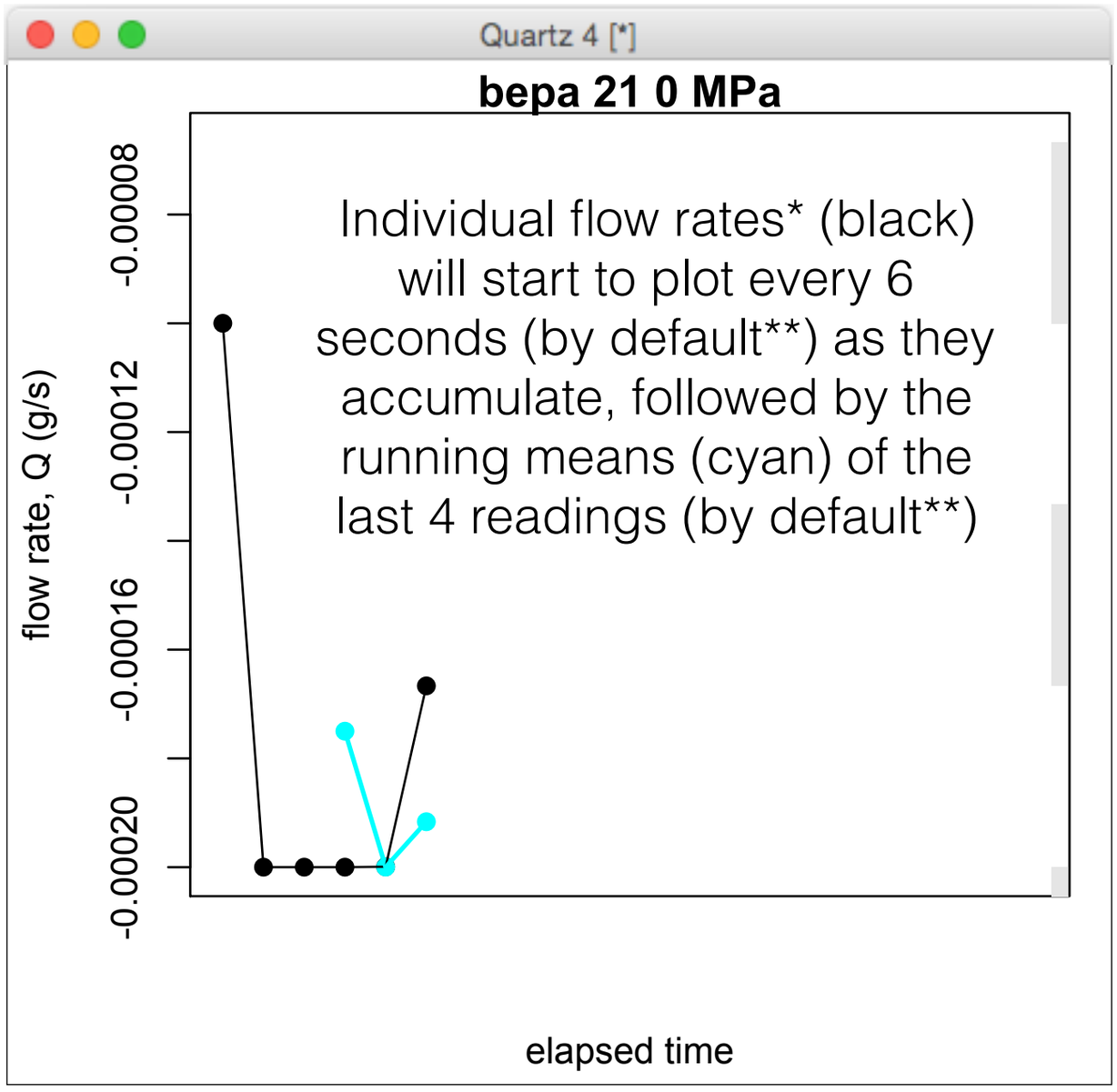


Making measurements with a balance



← the ‘Done!’ button should appear

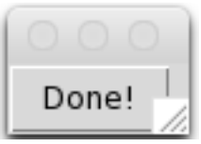


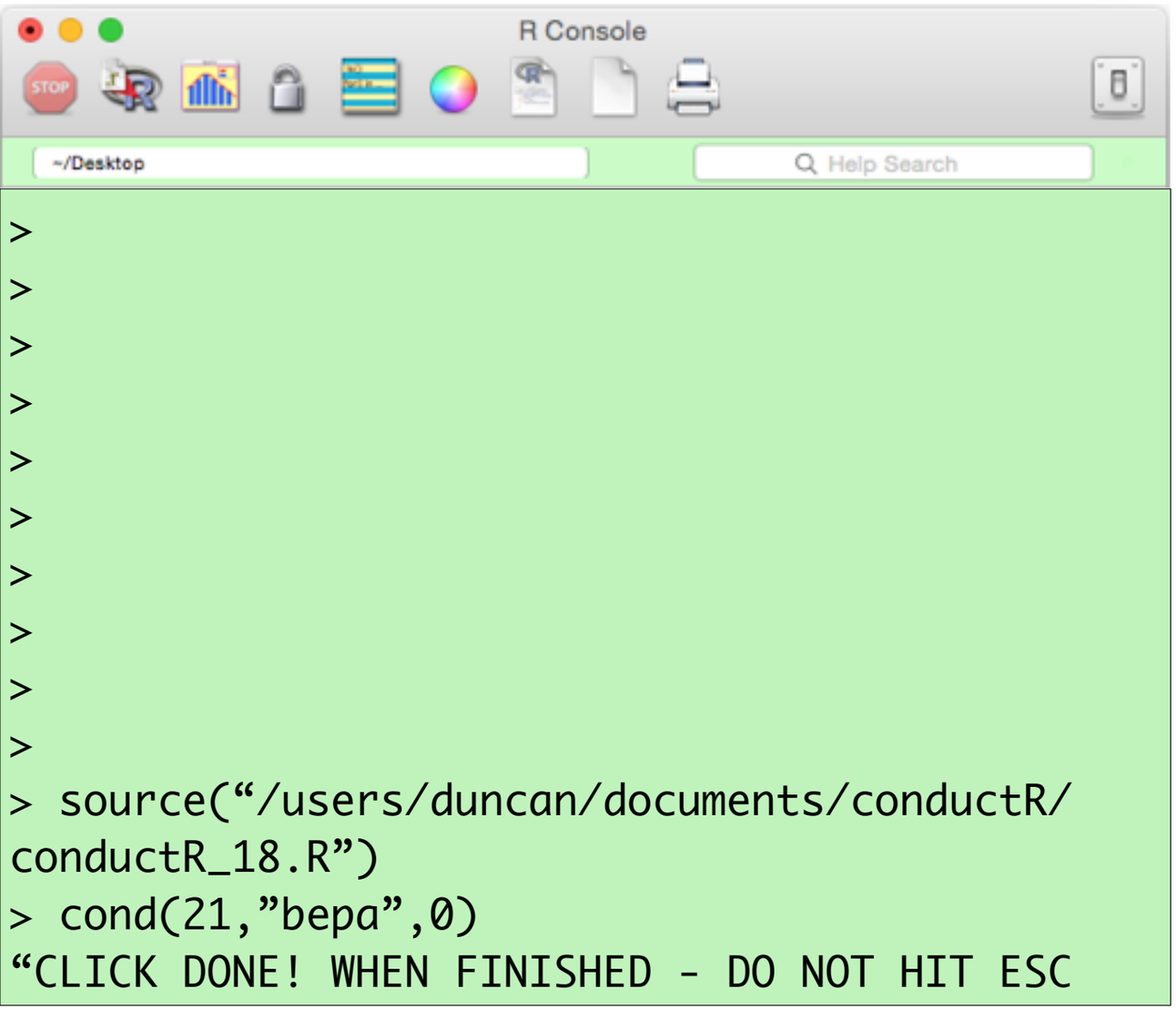


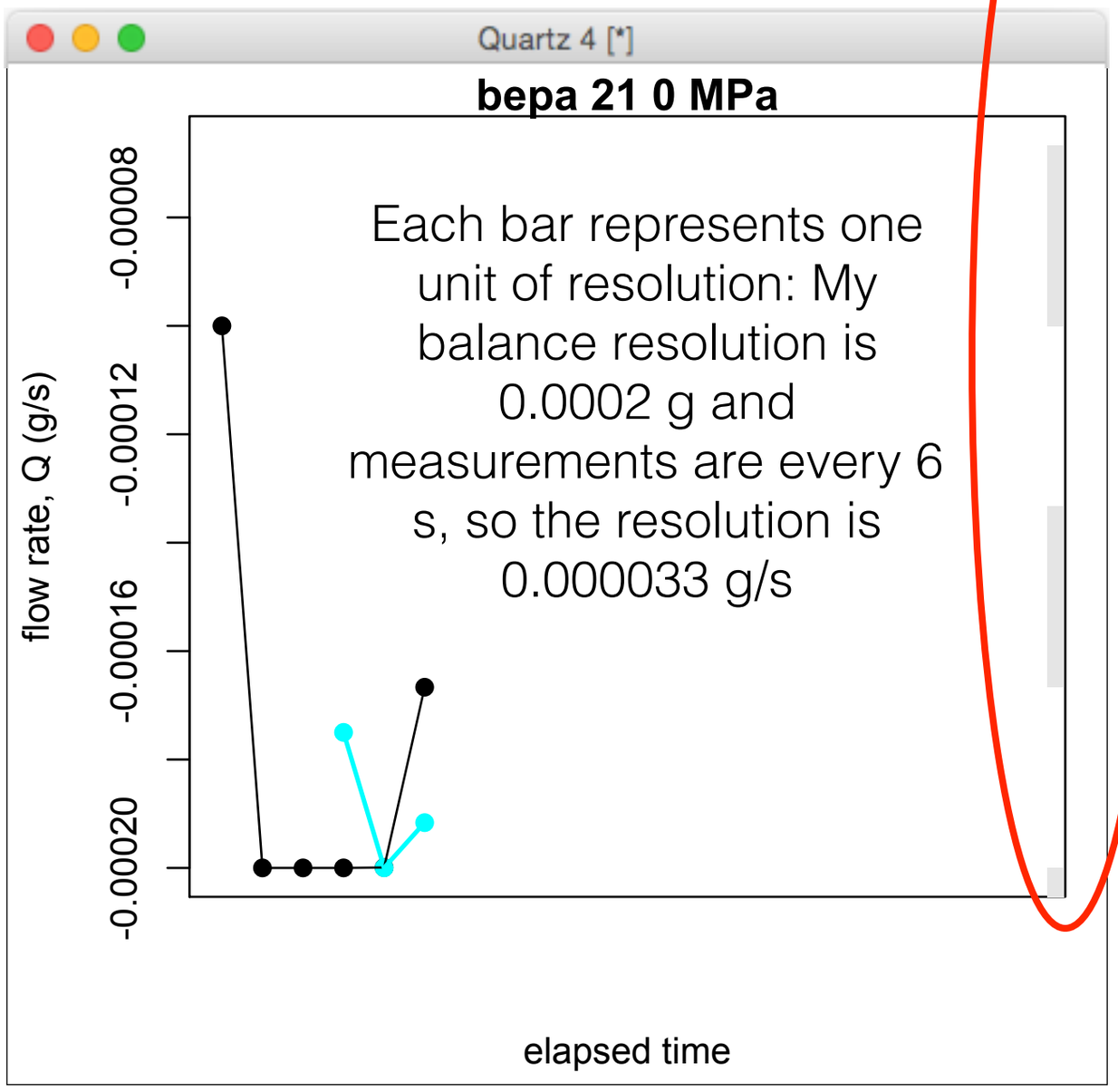
*here, rates are shown as g/s. In the newer version, mg/s is shown instead for ease of interpretation. Data are still recorded in g though.

**see Appendices A & E for details

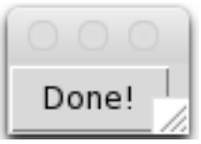
Making measurements with a balance

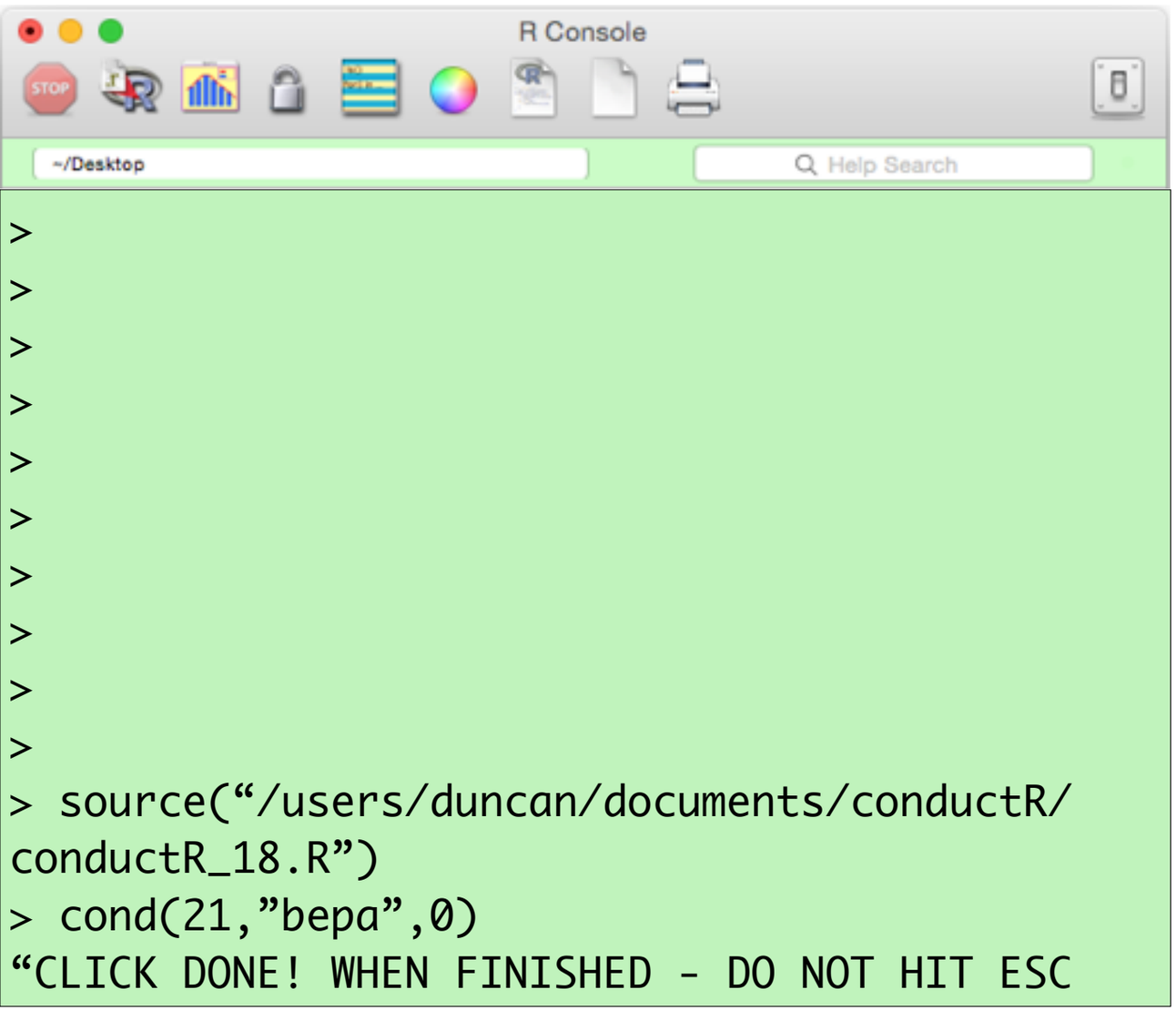


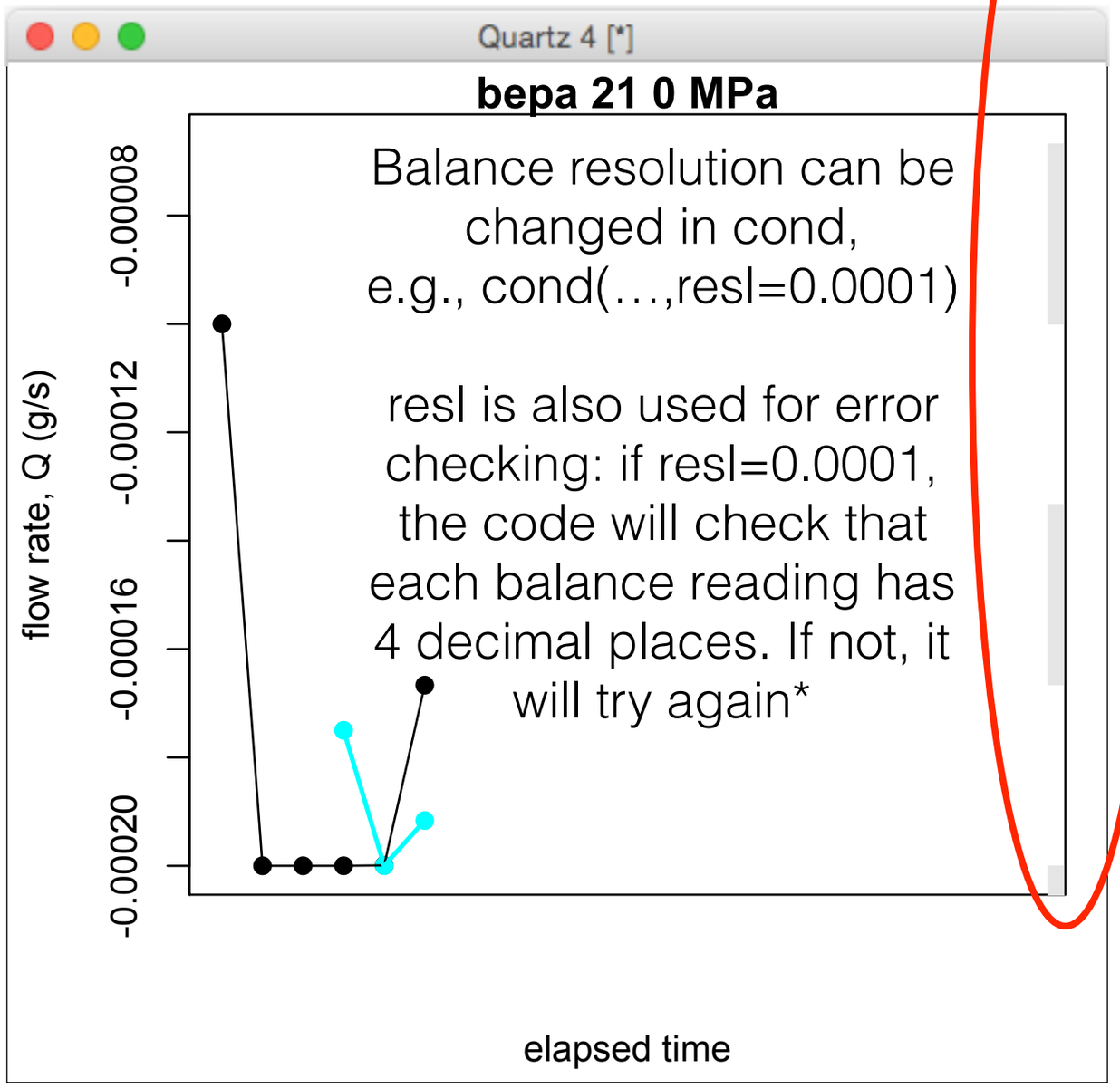




Making measurements with a balance

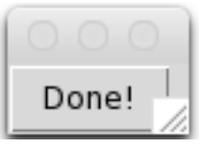


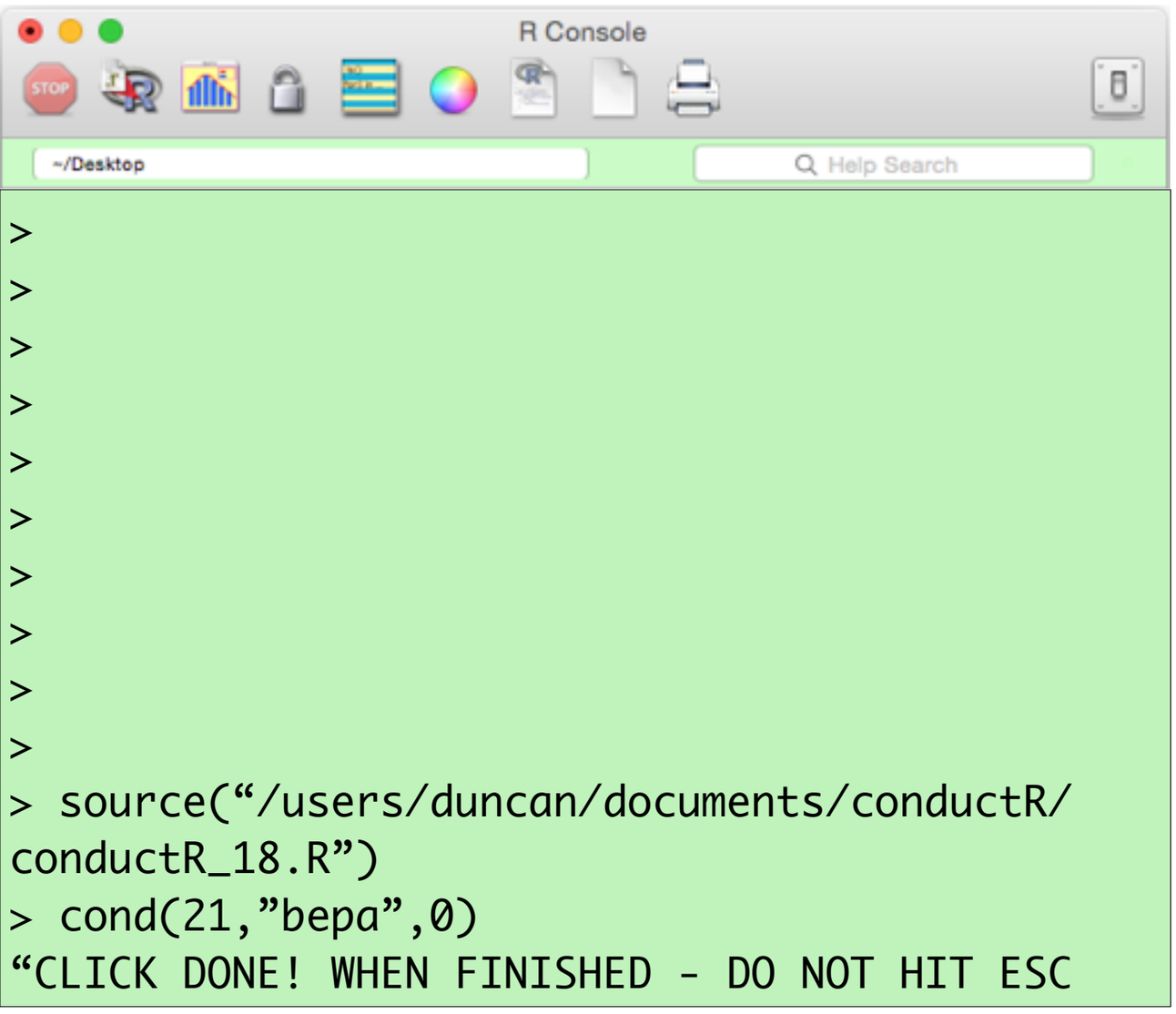


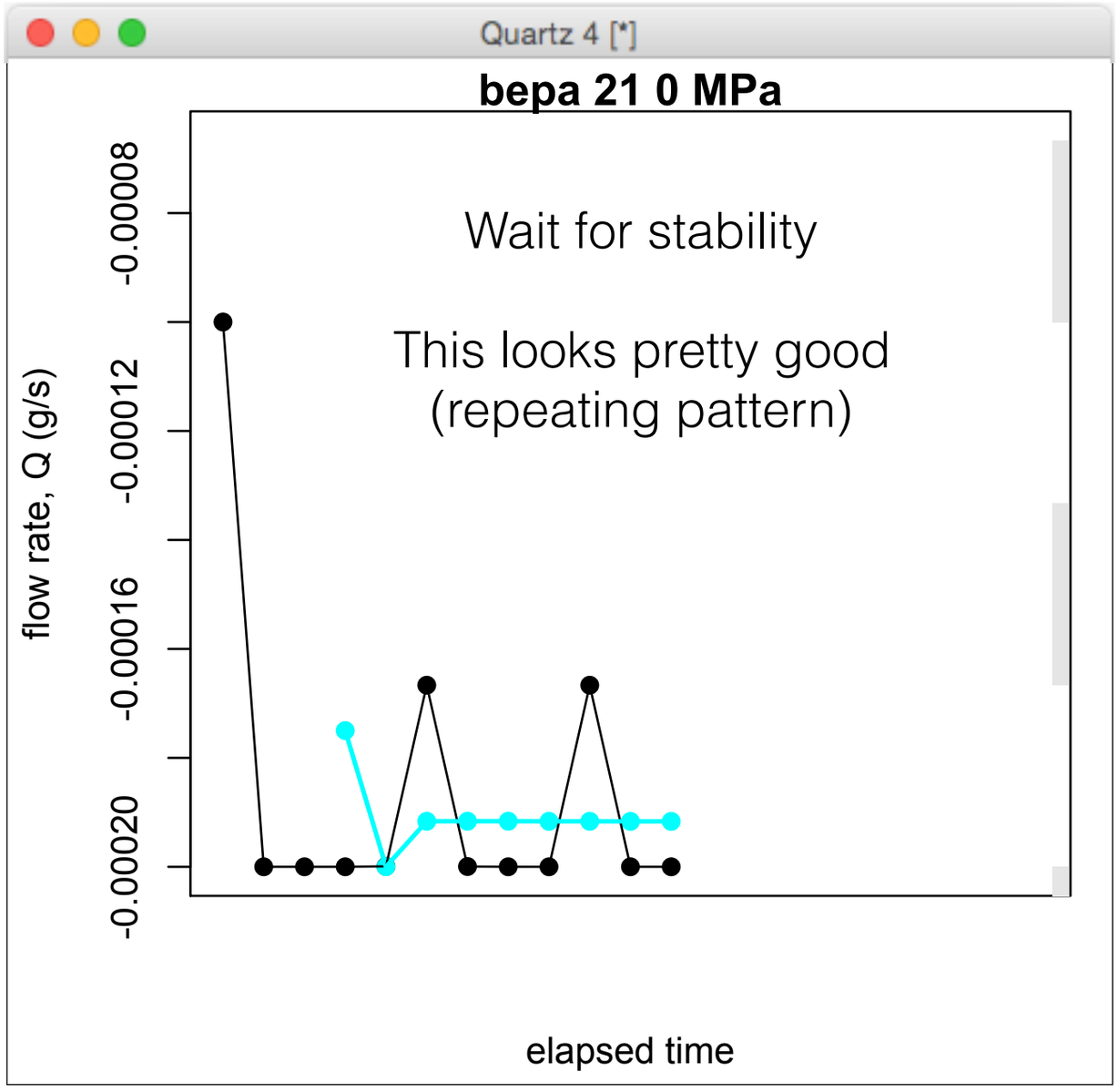


*In my experience, a Sartorius will occasionally drop the last digit, which if undetected, leads to a spike in the calculated flow rate. If too few decimals were received, the program will tell you this in the console.

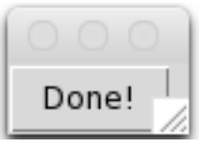
Making measurements with a balance

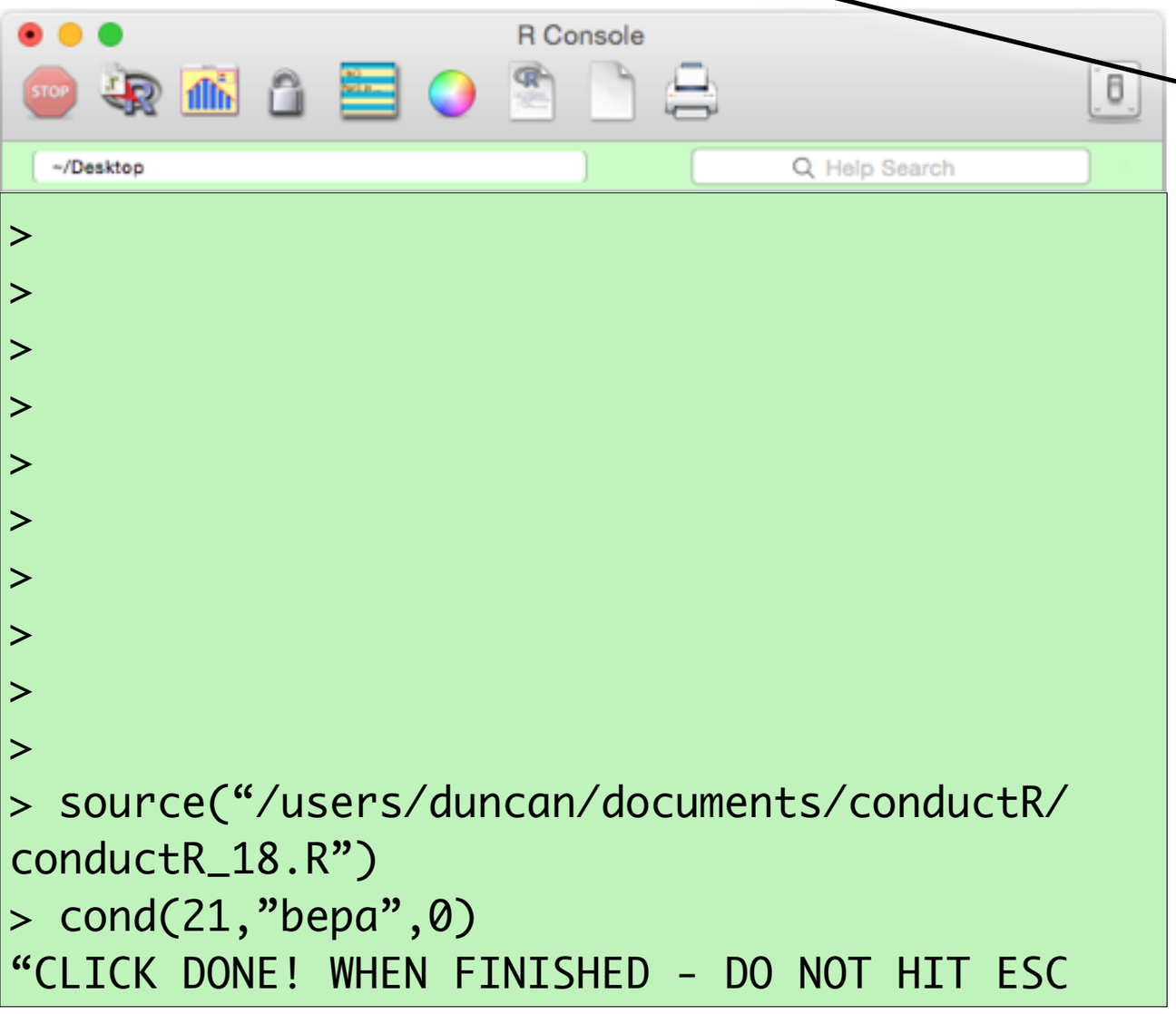


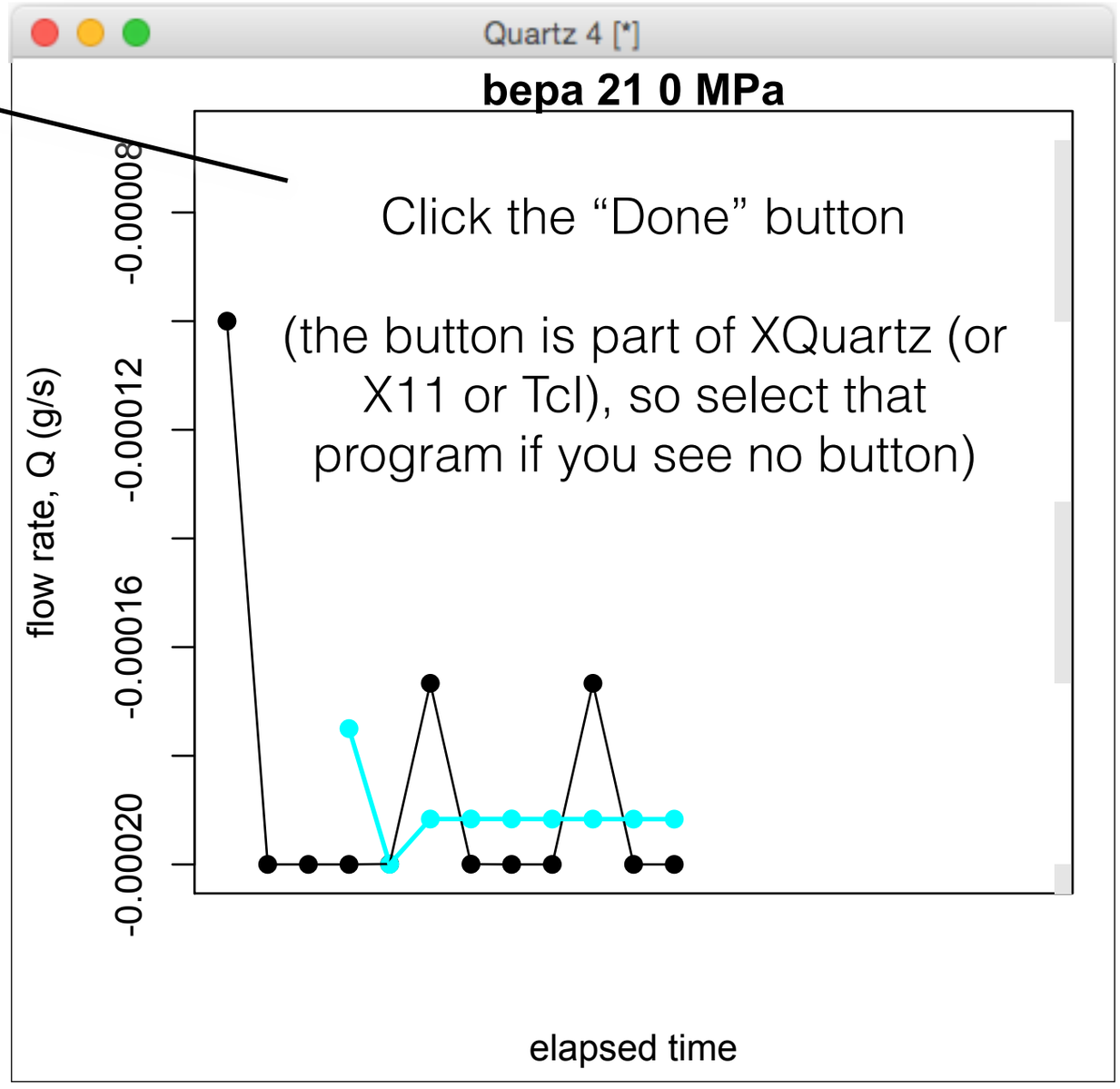




Making measurements with a balance







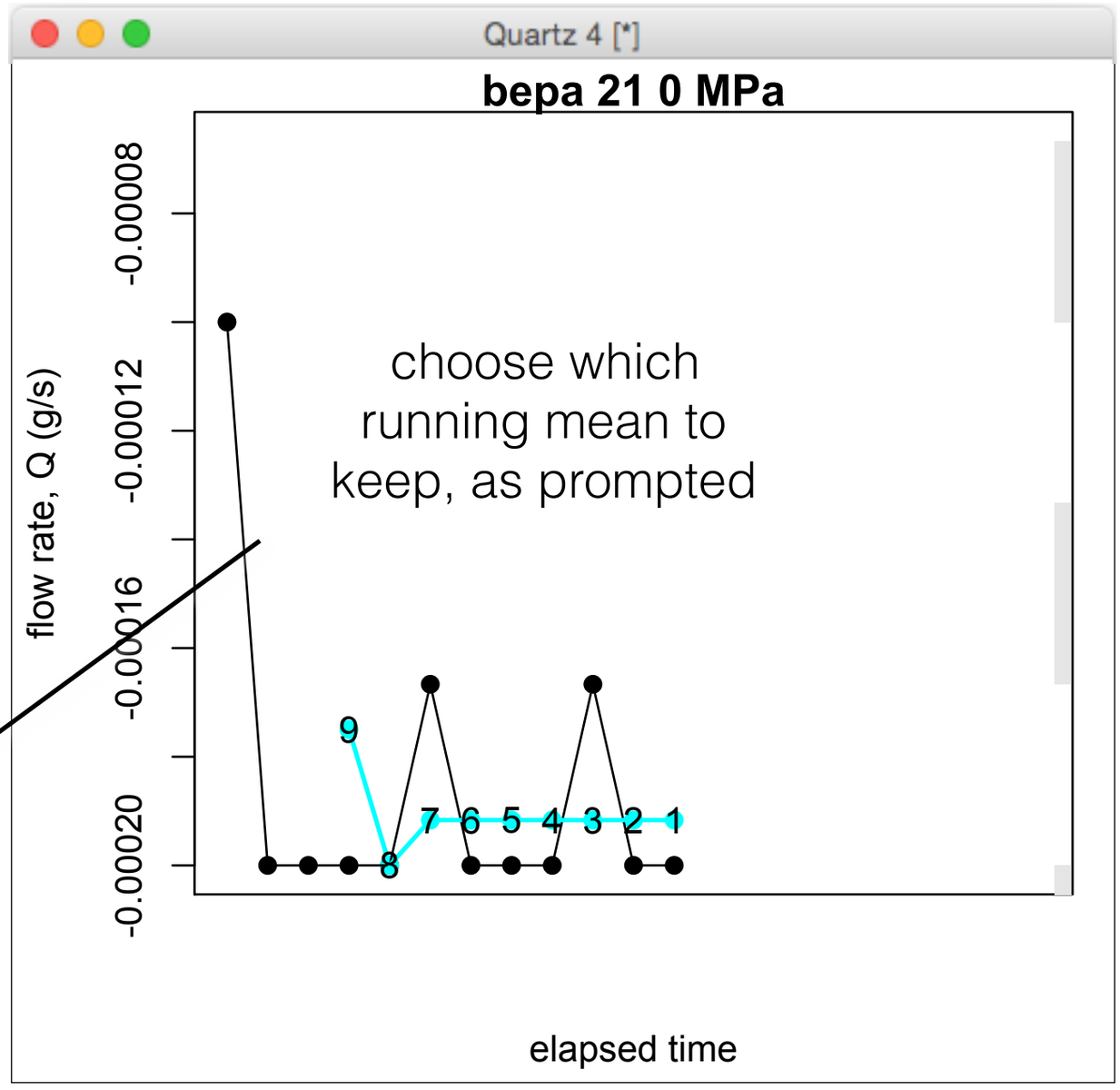
Making measurements with a balance

R Console

~/Desktop

Help Search

```
>
>
>
>
>
>
> source("/users/duncan/documents/conductR/
conductR_18.R")
> cond(21,"bepa",0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
```



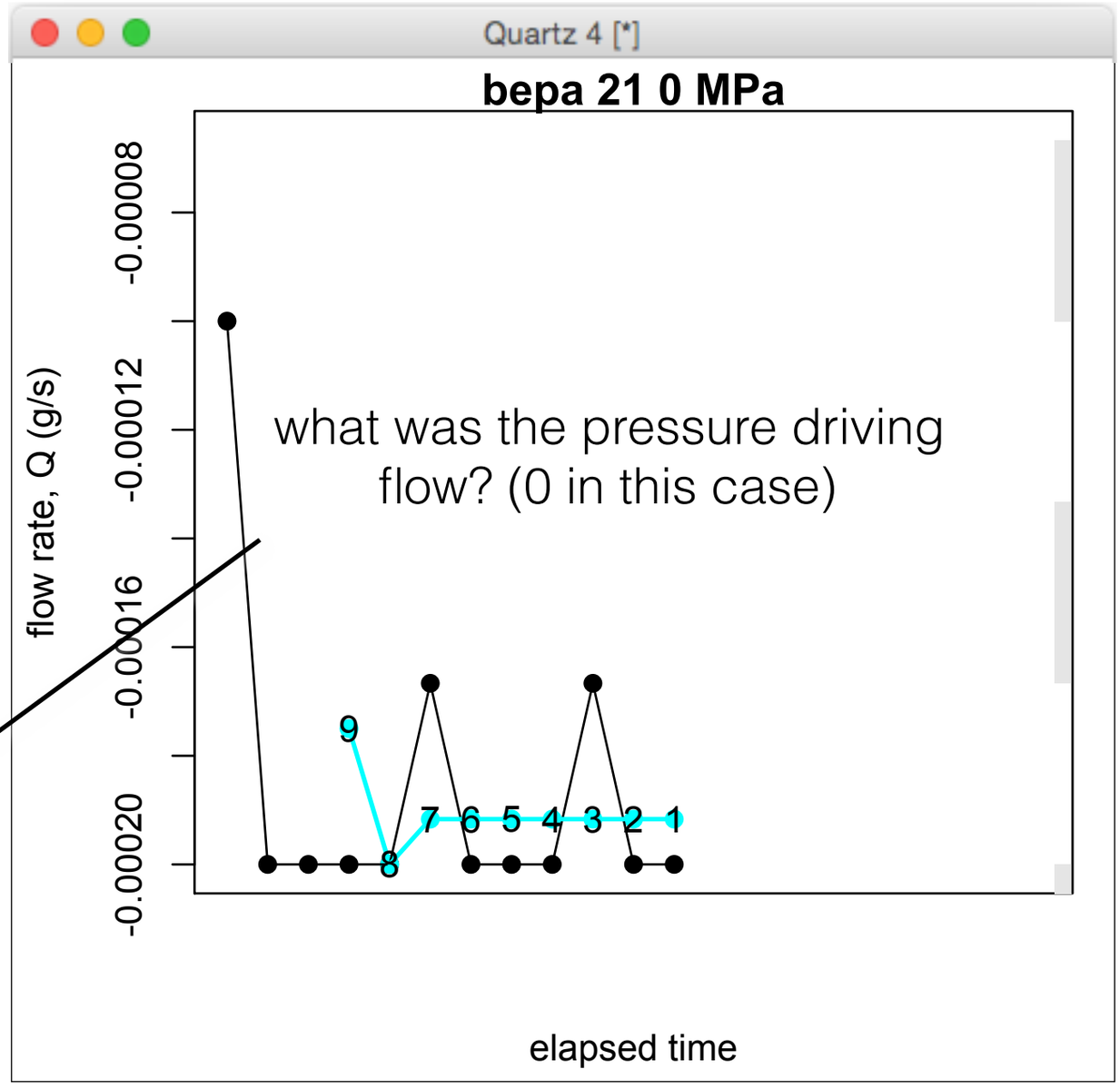
Making measurements with a balance

R Console

~/Desktop

Help Search

```
>
>
>
>
>
>
> source(“/users/duncan/documents/conductR/
conductR_18.R”)
> cond(21,”bepa”,0)
“CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
```



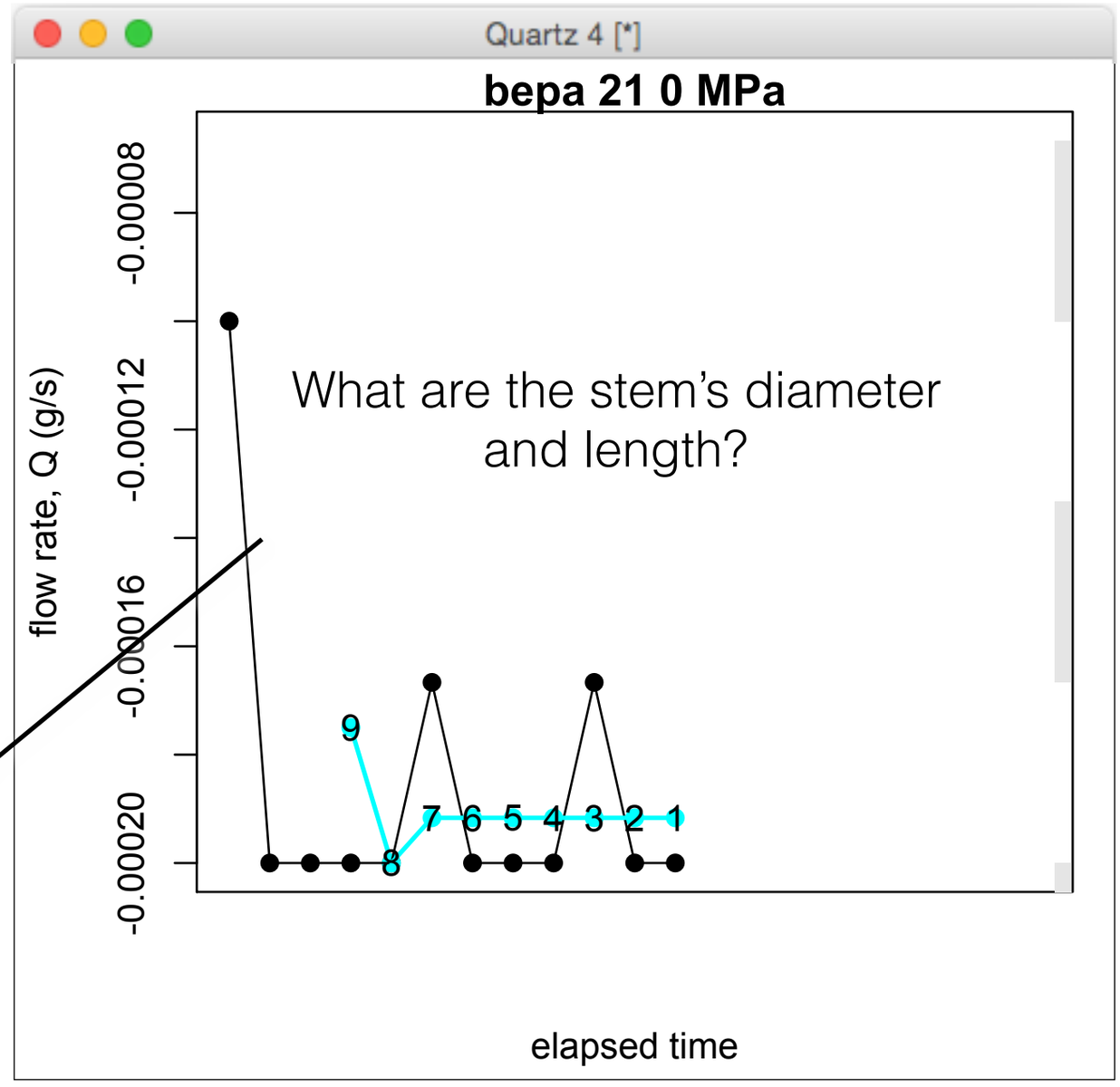
Making measurements with a balance

R Console

~/Desktop

Help Search

```
>
>
>
>
>
>
>
> source(“/users/duncan/documents/conductR/
conductR_18.R”)
> cond(21,”bepa”,0)
“CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
no previous diameter. d.mm=  5.2
no previous length. l.mm=  242
```



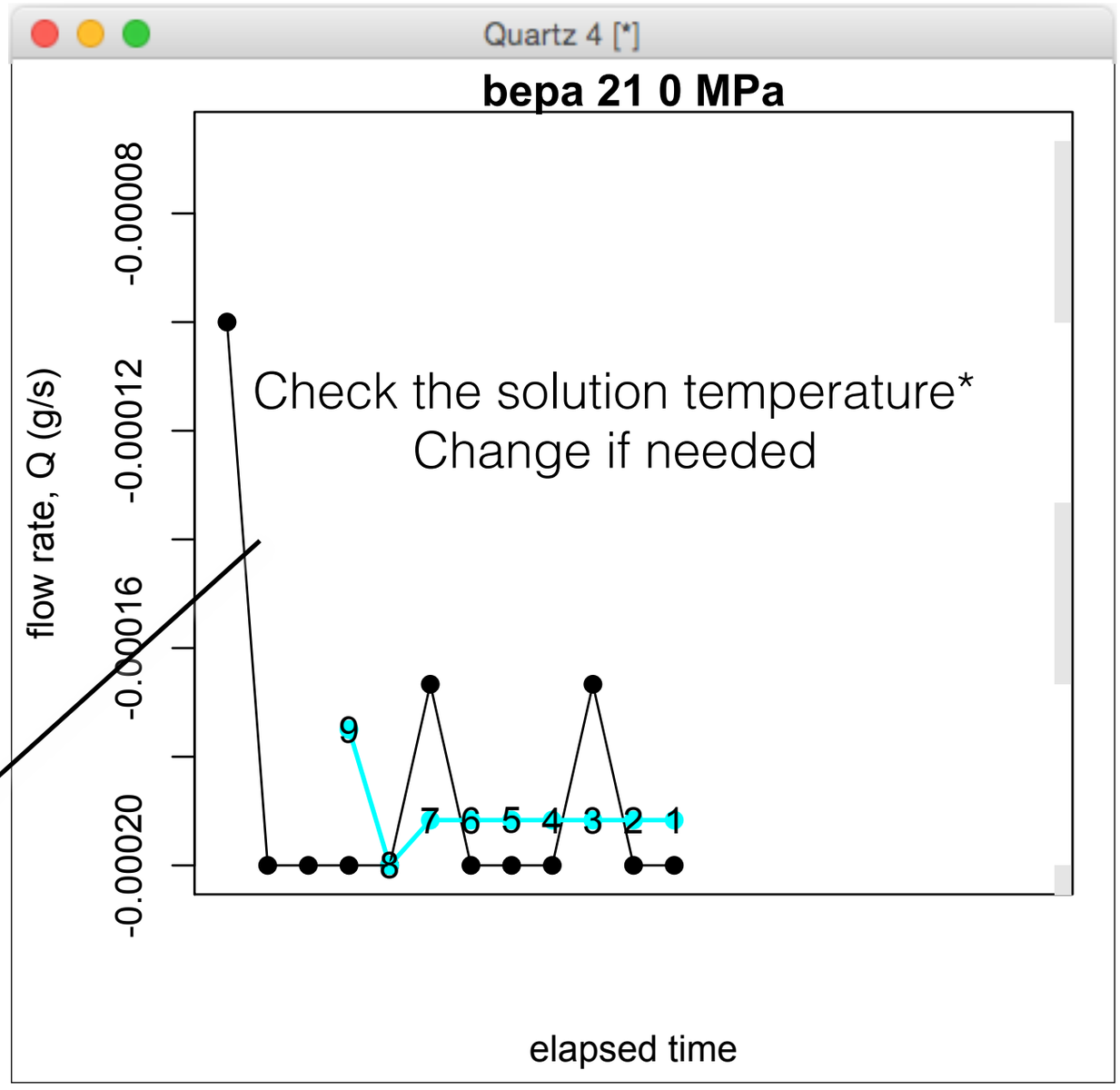
Making measurements with a balance

R Console

~/Desktop

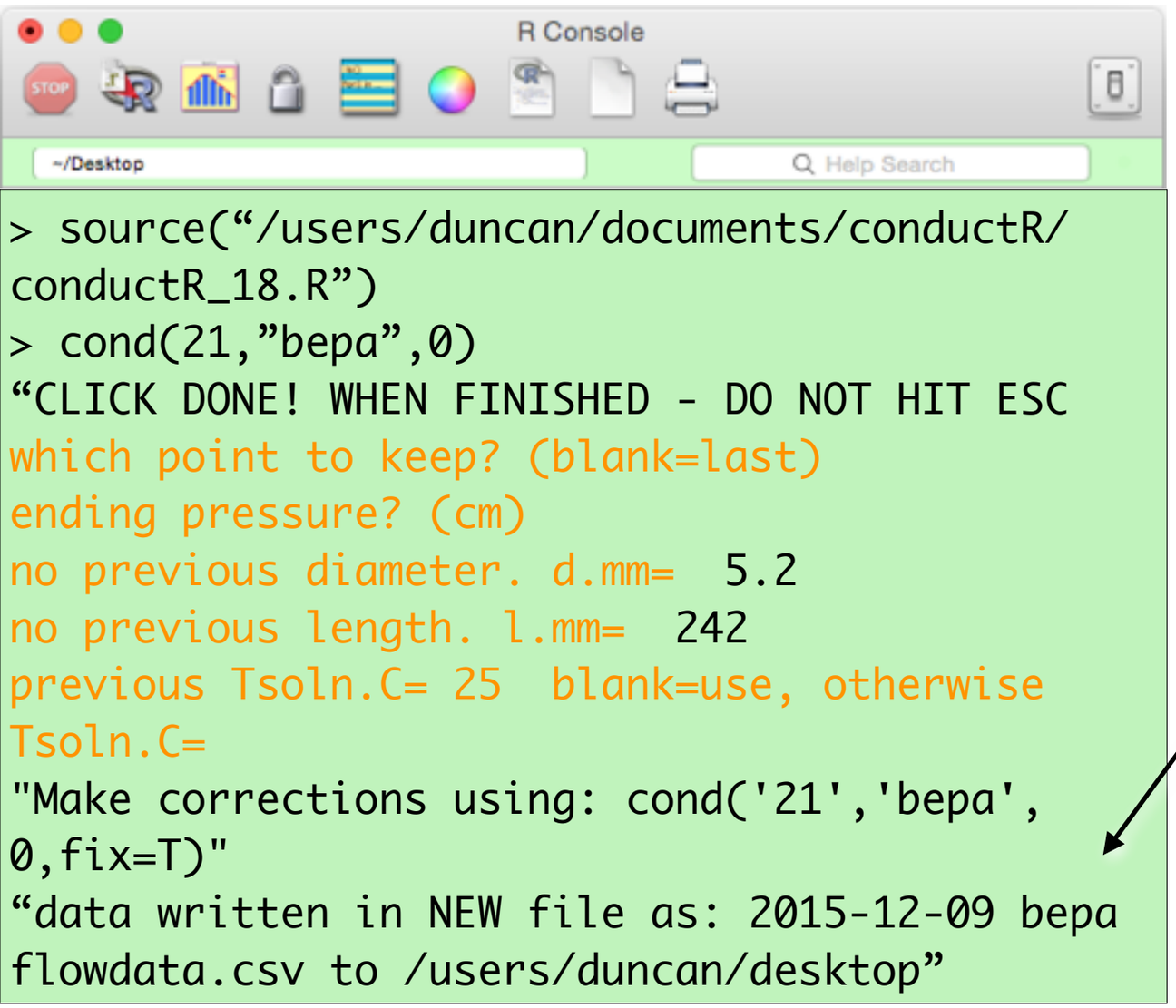
Help Search

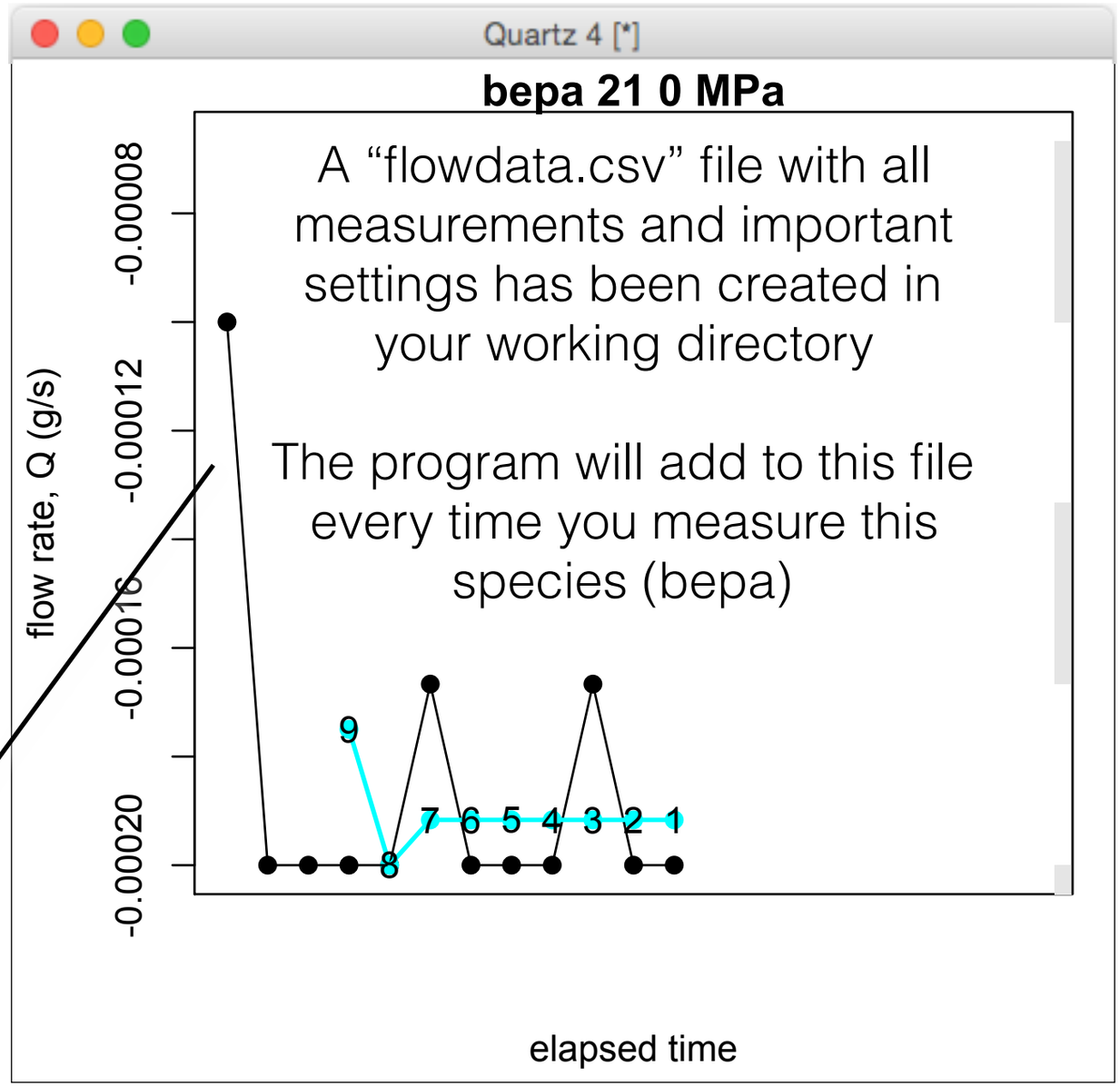
```
>
>
>
>
> source("/users/duncan/documents/conductR/
conductR_18.R")
> cond(21,"bepa",0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm)
no previous diameter. d.mm=  5.2
no previous length. l.mm=  242
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
```



*25 C is the default. Conductance will be standardized to 20 C later.

Making measurements with a balance





Note that date is added to the file name just to have some unique identifier for your convenience. The program ignores this, so change it if desired.

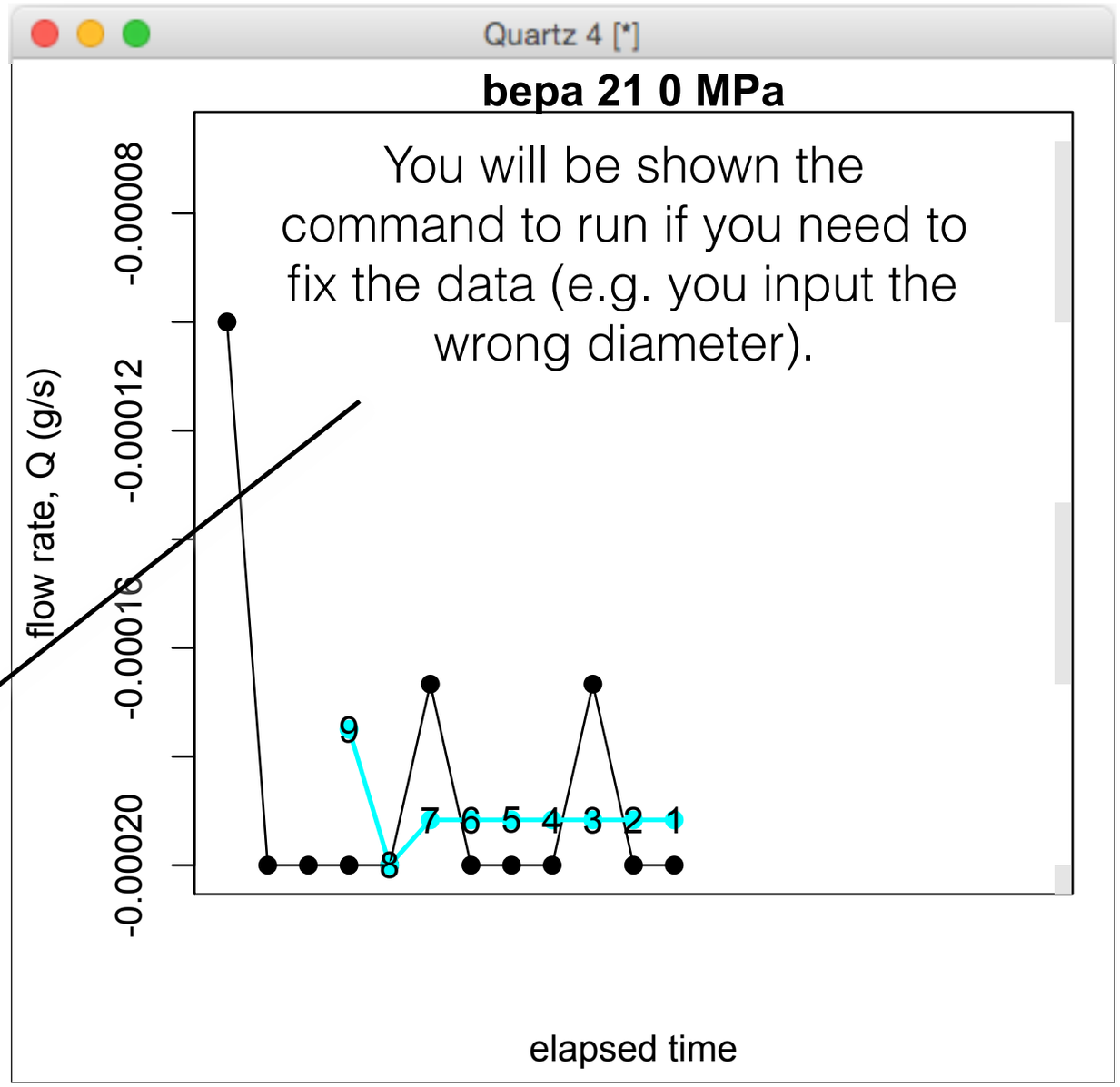
Making measurements with a balance

R Console

~/Desktop

Help Search

```
> source("/users/duncan/documents/conductR/
conductR_18.R")
> cond(21,"bepa",0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm)
no previous diameter. d.mm=  5.2
no previous length. l.mm=  242
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
"data written in NEW file as: 2015-12-09 bepa
flowdata.csv to /users/duncan/desktop"
```



Making measurements with a balance

The saved flowdata.csv file looks like this

sp	numbr	Ptreat.MPa	d.mm	l.mm	stemID	nomID	t.s	t.day	dt.s	bal.g	Q.g.s
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	0	209.5402859594	NA	82.7735	NA
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	6.7997770309	209.5403646606	6.7997770309	82.7691	0.00064708
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	13.6095688343	209.5404434776	6.8097918034	82.7648	0.0006314437
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	20.4193608761	209.5405222946	6.8097920418	82.7619	0.0004258574
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	27.2291529179	209.5406011117	6.8097920418	82.7576	0.0006314437
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	34.0189158916	209.5406796969	6.7897629738	82.7532	0.0006480344
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	40.7986650467	209.5407581662	6.779749155	82.749	0.0006194919
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	47.5984430313	209.5408368674	6.7997779846	82.7461	0.0004264845
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	54.3982200623	209.5409155685	6.7997770309	82.7418	0.0006323737
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	61.2280409336	209.5409946173	6.8298208714	82.7376	0.0006149502
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	68.0178039074	209.5410732025	6.7897629738	82.7333	0.0006333063
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	74.7975530624	209.5411516719	6.779749155	82.7304	0.0004277444
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	81.5973310471	209.541230373	6.7997779846	82.7261	0.0006323736
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	88.4071228504	209.54130919	6.8097918034	82.7219	0.0006167589
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	95.2068998814	209.5413878912	6.7997770309	82.719	0.0004264846
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	101.9966640472	209.5414664764	6.7897641659	82.7147	0.0006333062
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	108.786427021	209.5415450616	6.7897629738	82.7103	0.0006480344
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	115.586204052	209.5416237627	6.7997770309	82.7062	0.0006029609
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	122.3959958553	209.5417025798	6.8097918034	82.7035	0.0003964879
bepa	21	0	6.4	241	bepa 21	bepa 21 0 MPa	129.19577384	209.5417812809	6.7997779846	82.6991	0.00064708

species (or other group name)

individual number

treatment pressure

stem diameter

stem length

species and number (used by program for grouping)

stem ID and treatment (used by program for grouping)

time (s) since starting measurement

time (decimal day) balance was read

time (s) between reading balance

balance reading

flow rate (g/s)

continued…

Making measurements with a balance

The saved flowdata.csv file looks like this

rmQ.g.s	p.cm	p.MPa	Tsoln.C	keep	usefork	measure	ver
NA	54.5	0.0042423796	25	FALSE	FALSE	1	v18
NA	54.5	0.0042423796	25	FALSE	FALSE	1	v18
NA	54.5	0.0042423796	25	FALSE	FALSE	1	v18
NA	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005839562	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005841948	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005812068	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005813636	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005815961	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005733251	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005767787	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005770937	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005770937	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005775458	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005258404	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005772308	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.000581146	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005776965	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005701974	54.5	0.0042423796	25	FALSE	FALSE	1	v18
0.0005736408	54.5	0.0042423796	25	TRUE	FALSE	1	v18

running mean flow rate (g/s)

hydraulic head (cm)

head converted to MPa

solution temperature

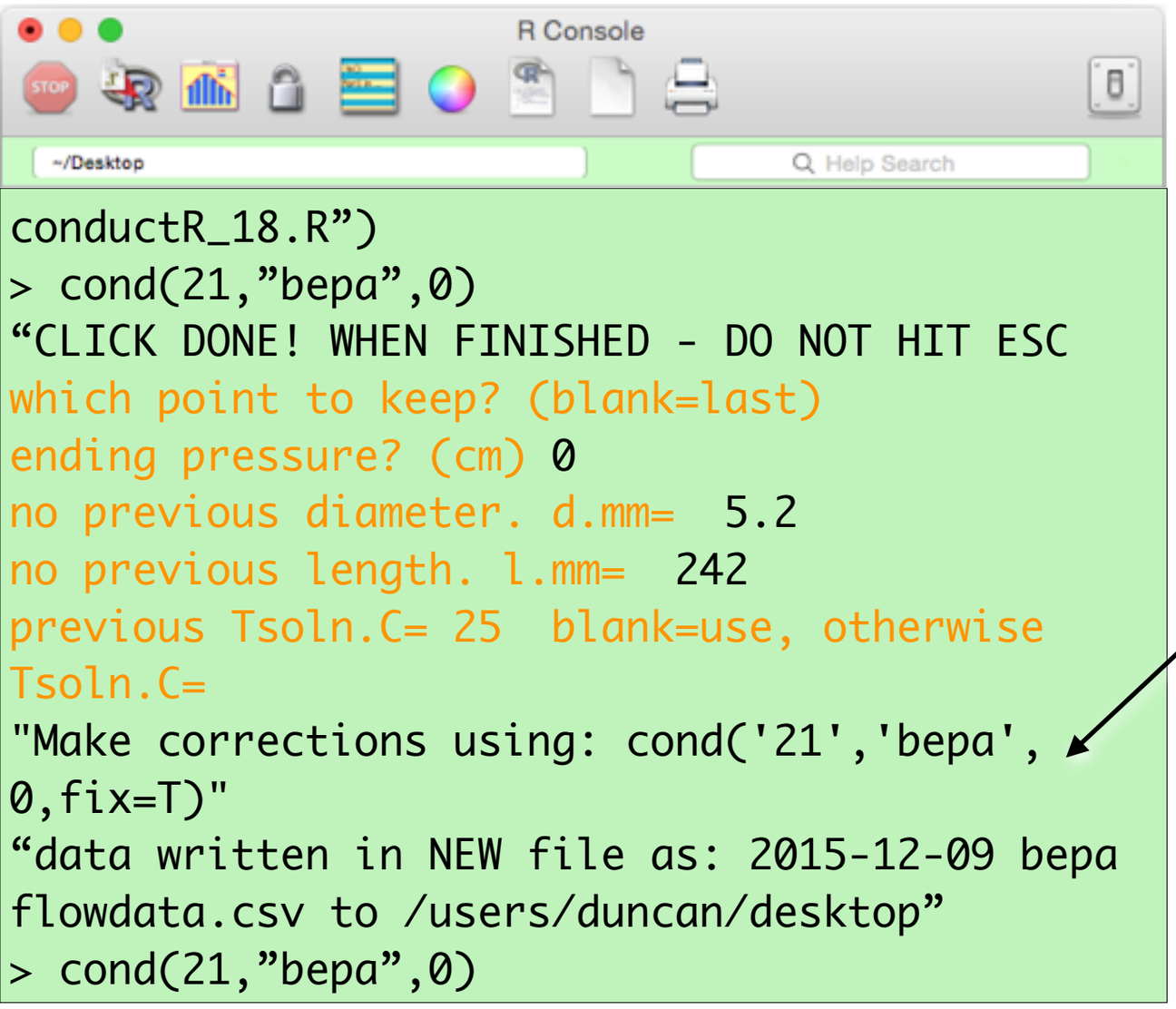
point in measurement to keep

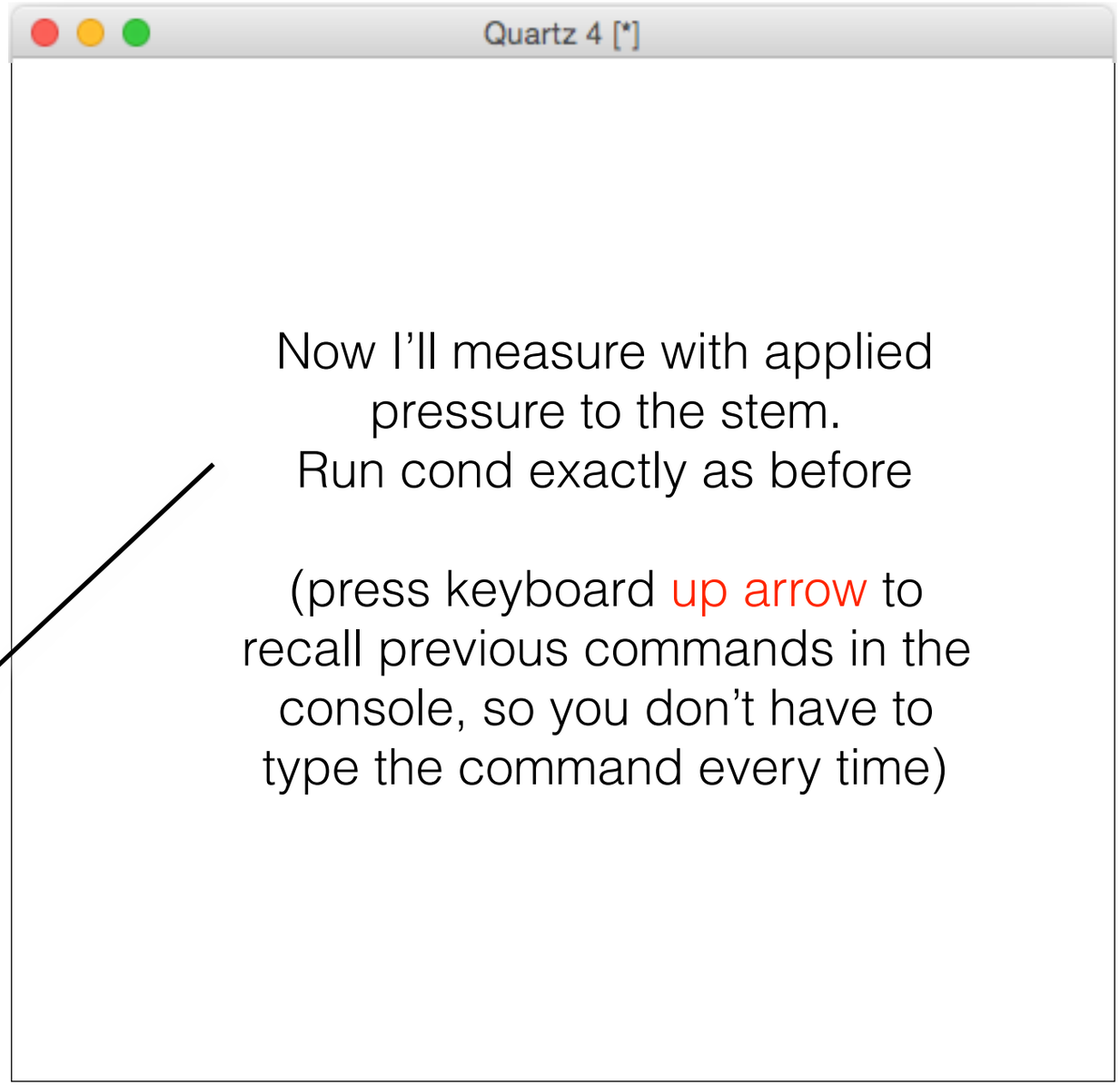
point(s) used to calculate conductance

measurement number (mostly used by program when fixing errors)

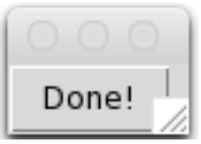
conductR version

Making measurements with a balance



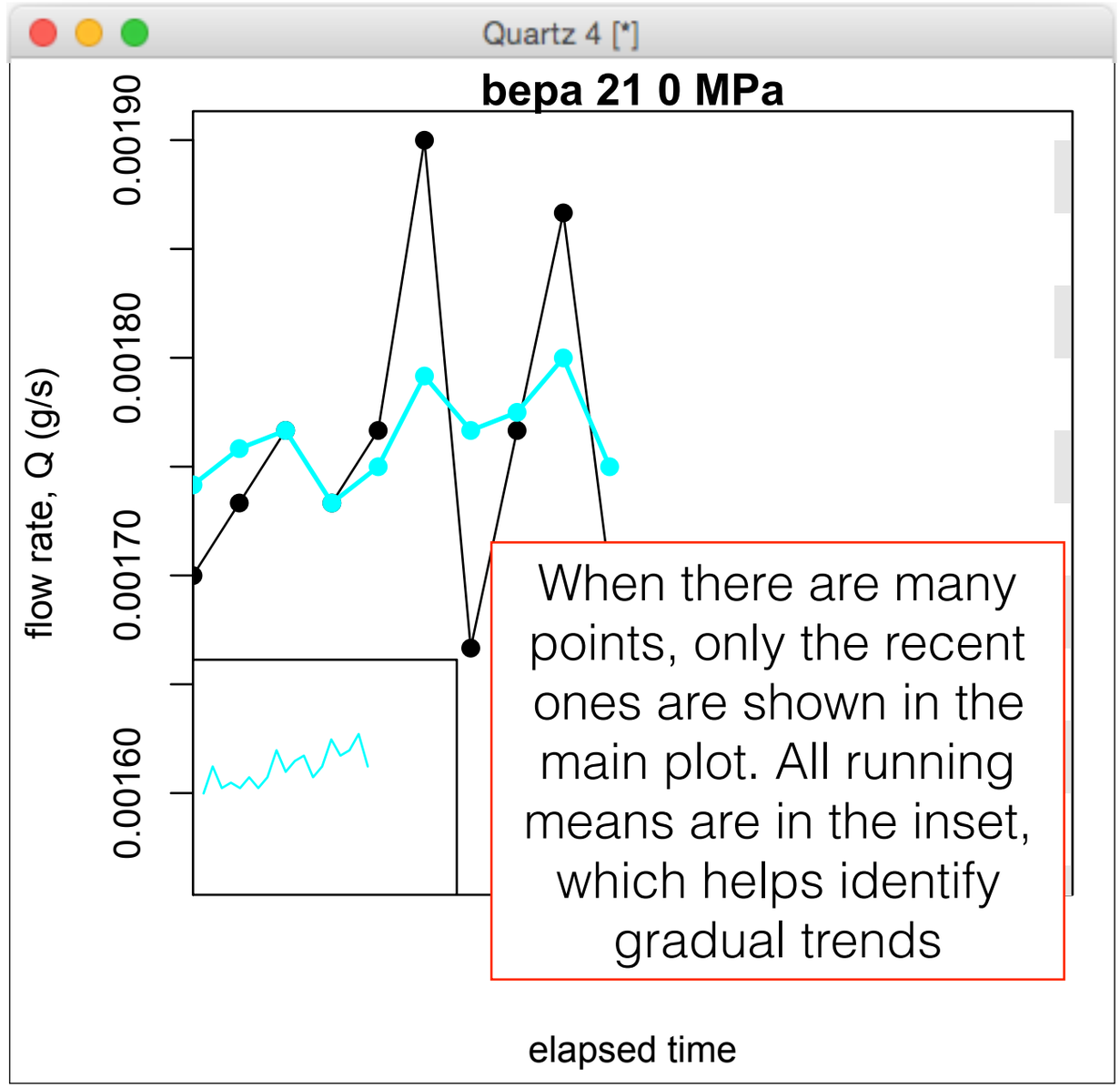


Making measurements with a balance



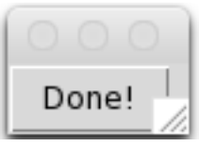
R Console

```
> cond(21,"bepa",0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
no previous diameter. d.mm=  5.2
no previous length. l.mm=  242
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
"data written in NEW file as: 2015-12-09 bepa
flowdata.csv to /users/duncan/desktop"
> cond(21,"bepa",0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!"
```



Inset size (as a fraction of total plot size) is controlled by ovrl in cond. See Appendix A

Making measurements with a balance

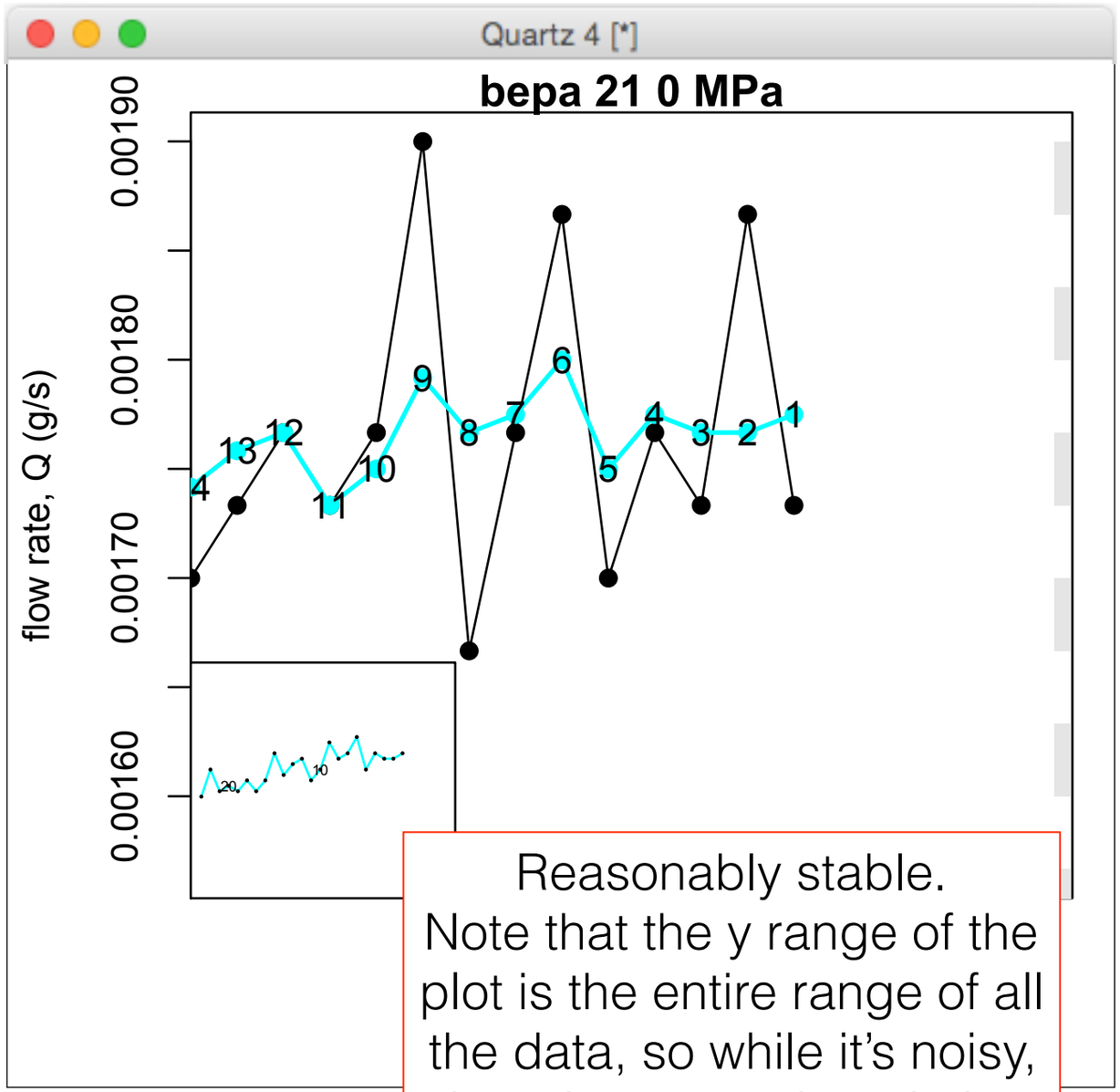


R Console

~/Desktop

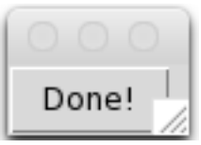
Help Search

```
> cond(21,”bepa”,0)
“CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
no previous diameter. d.mm=  5.2
no previous length. l.mm=  242
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data written in NEW file as: 2015-12-09 bepa
flowdata.csv to /users/duncan/desktop”
> cond(21,”bepa”,0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!"
```



Reasonably stable.
Note that the y range of the plot is the entire range of all the data, so while it’s noisy, there is not much variation in terms of measurement resolution (grey bars)

Making measurements with a balance

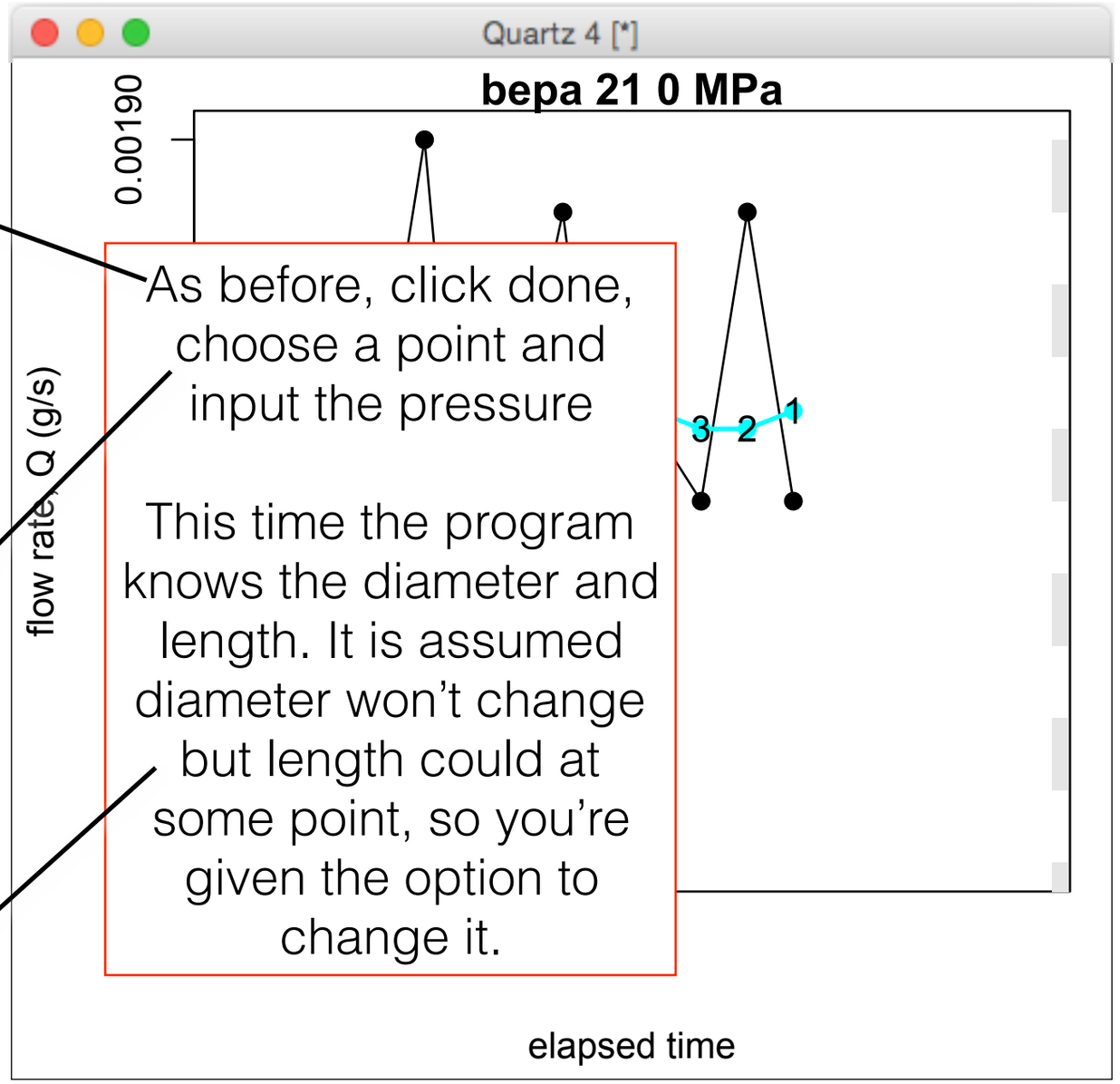


R Console

~/Desktop

Help Search

```
ending pressure? (cm)
no previous diameter. d.mm=  5.2
no previous length. l.mm=  242
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data written in NEW file as: 2015-12-09 bepa
flowdata.csv to /users/duncan/desktop”
> cond(21,”bepa”,0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!”
which point to keep? (blank=last)
ending pressure? (cm) 66.6
previous l.mm=242 blank=use otherwise l.mm=
```



As before, click done, choose a point and input the pressure

This time the program knows the diameter and length. It is assumed diameter won’t change but length could at some point, so you’re given the option to change it.

*if you change length or diameter partway through a conductivity measurement, the program will use the most recent values to calculate conductivity. It is NOT assumed the physical dimensions changed during measurement.

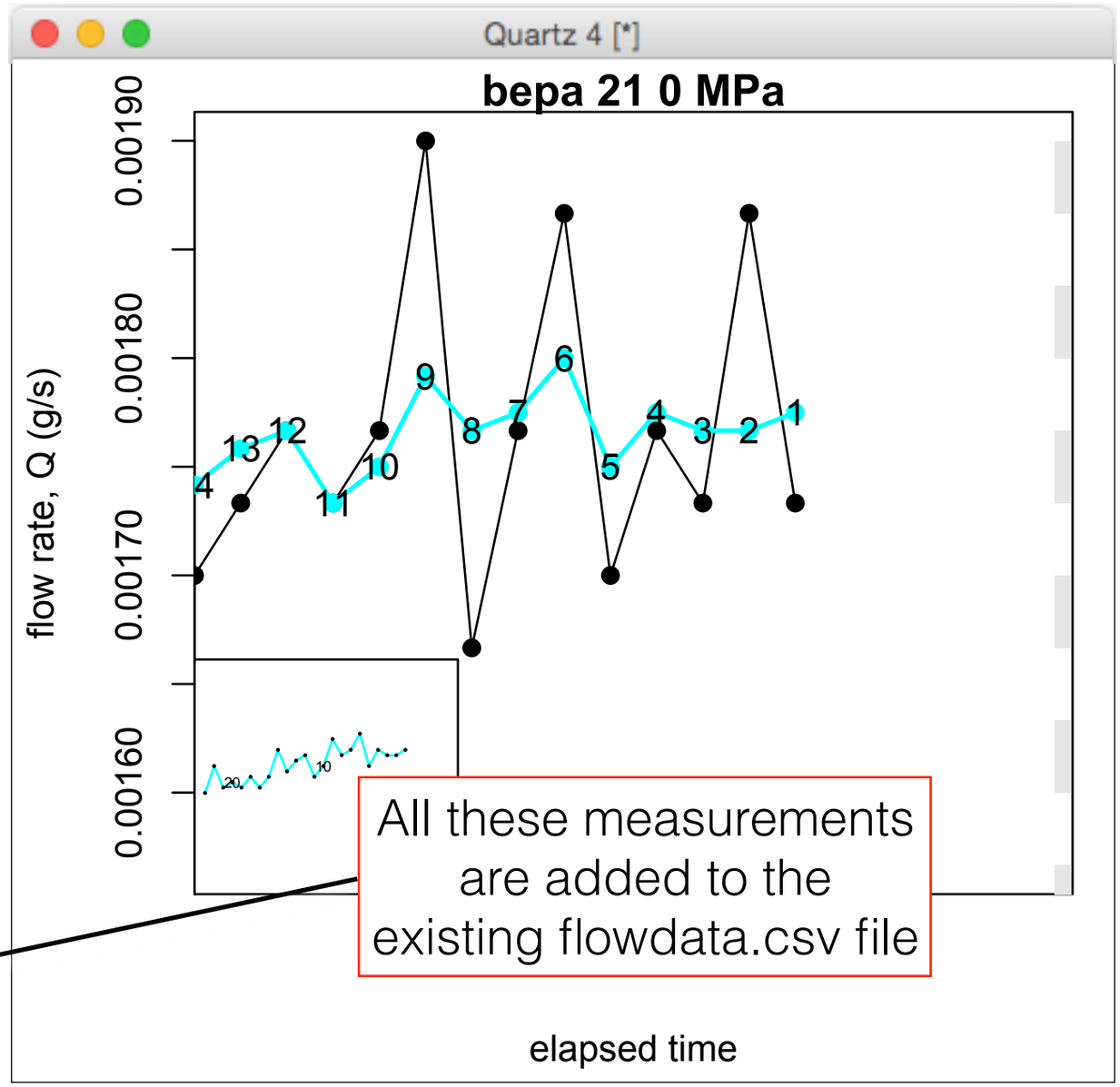
Making measurements with a balance

R Console

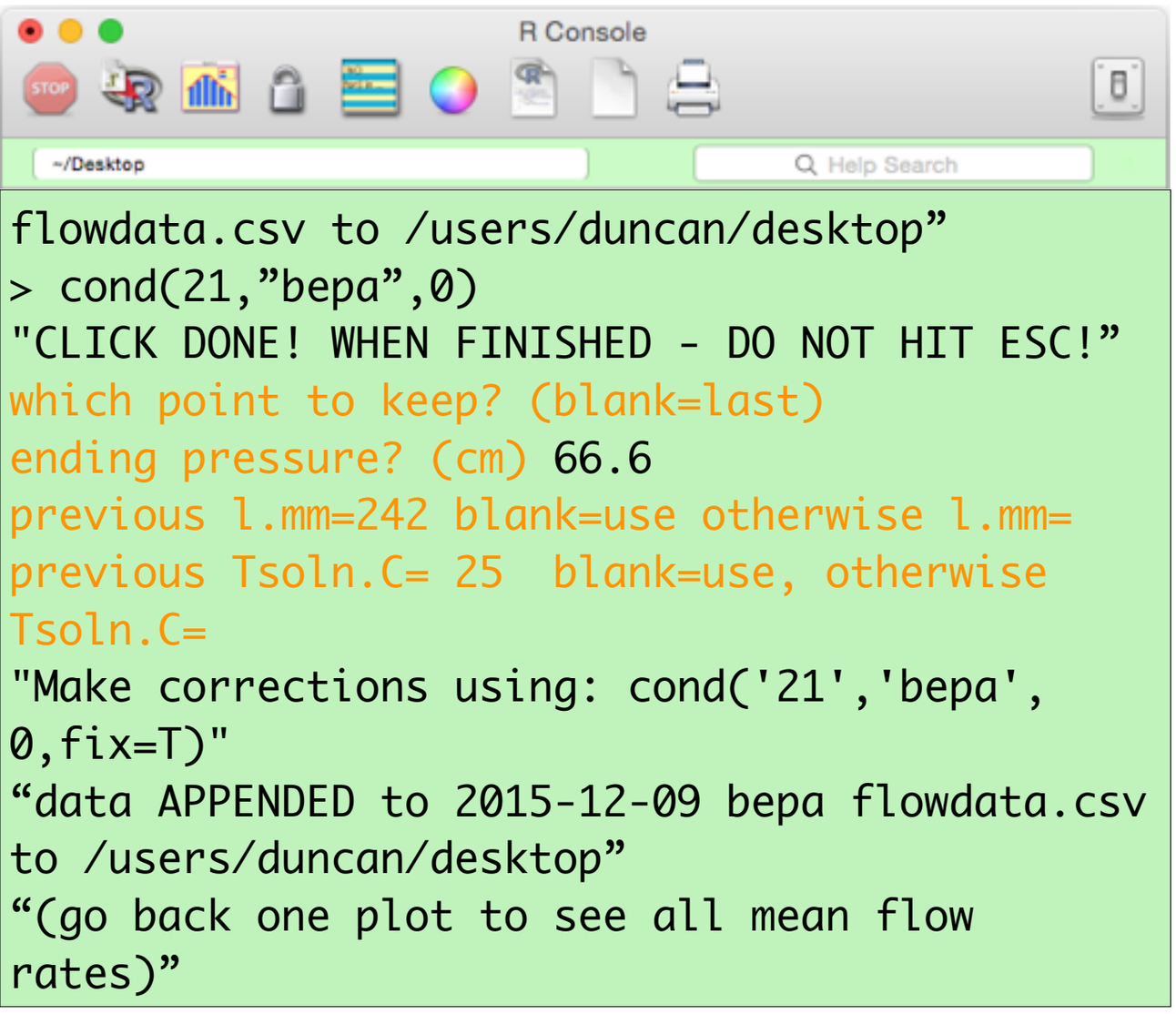
~/Desktop

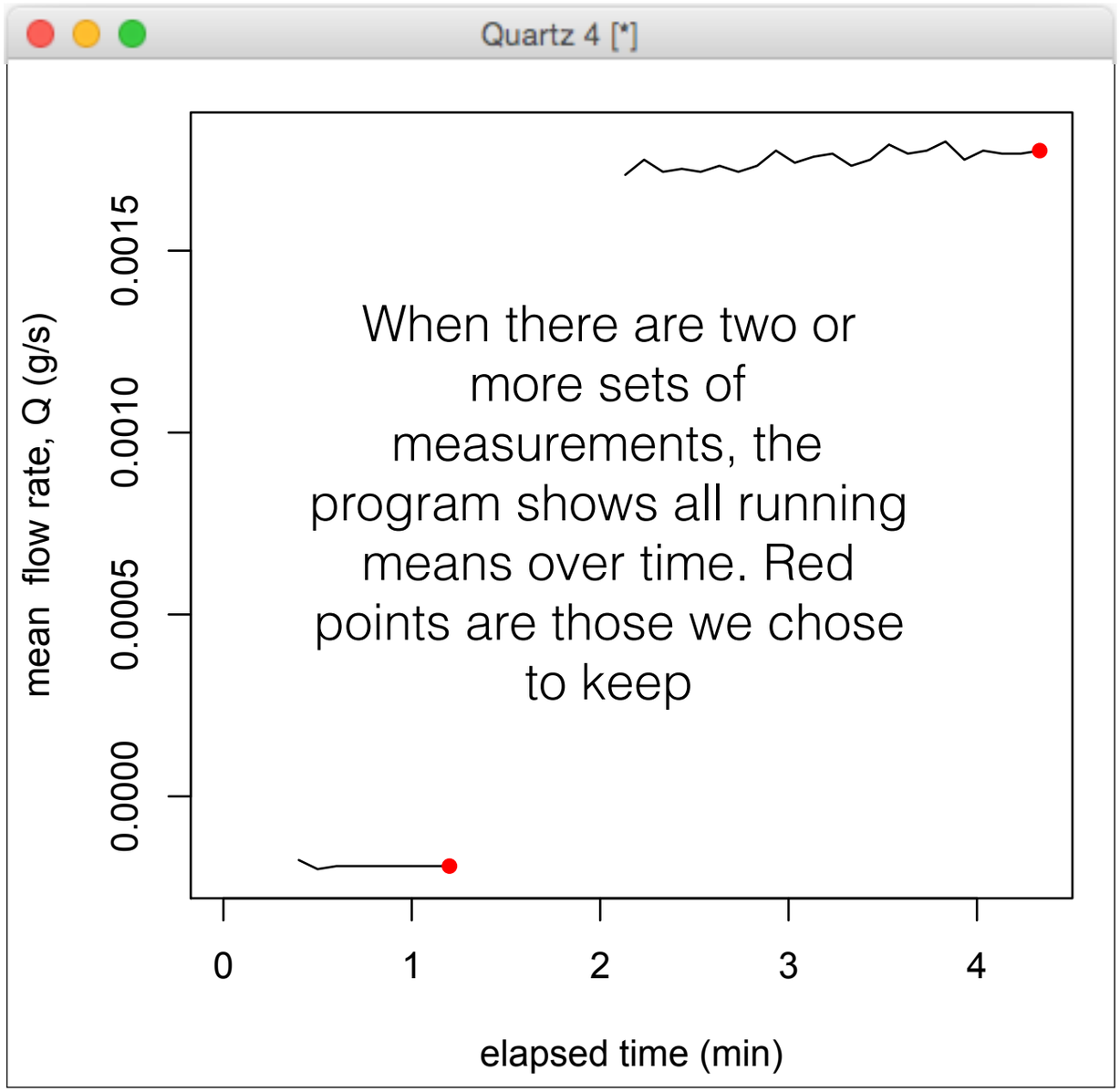
Help Search

```
“data written in NEW file as: 2015-12-09 bepa
flowdata.csv to /users/duncan/desktop”
> cond(21,”bepa”,0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!”
which point to keep? (blank=last)
ending pressure? (cm) 66.6
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop”
```



Making measurements with a balance





The program shows this plot for only 1 second before making the next plot. To toggle through plots, select Quartz window and use left and right arrow keys while holding ⌘

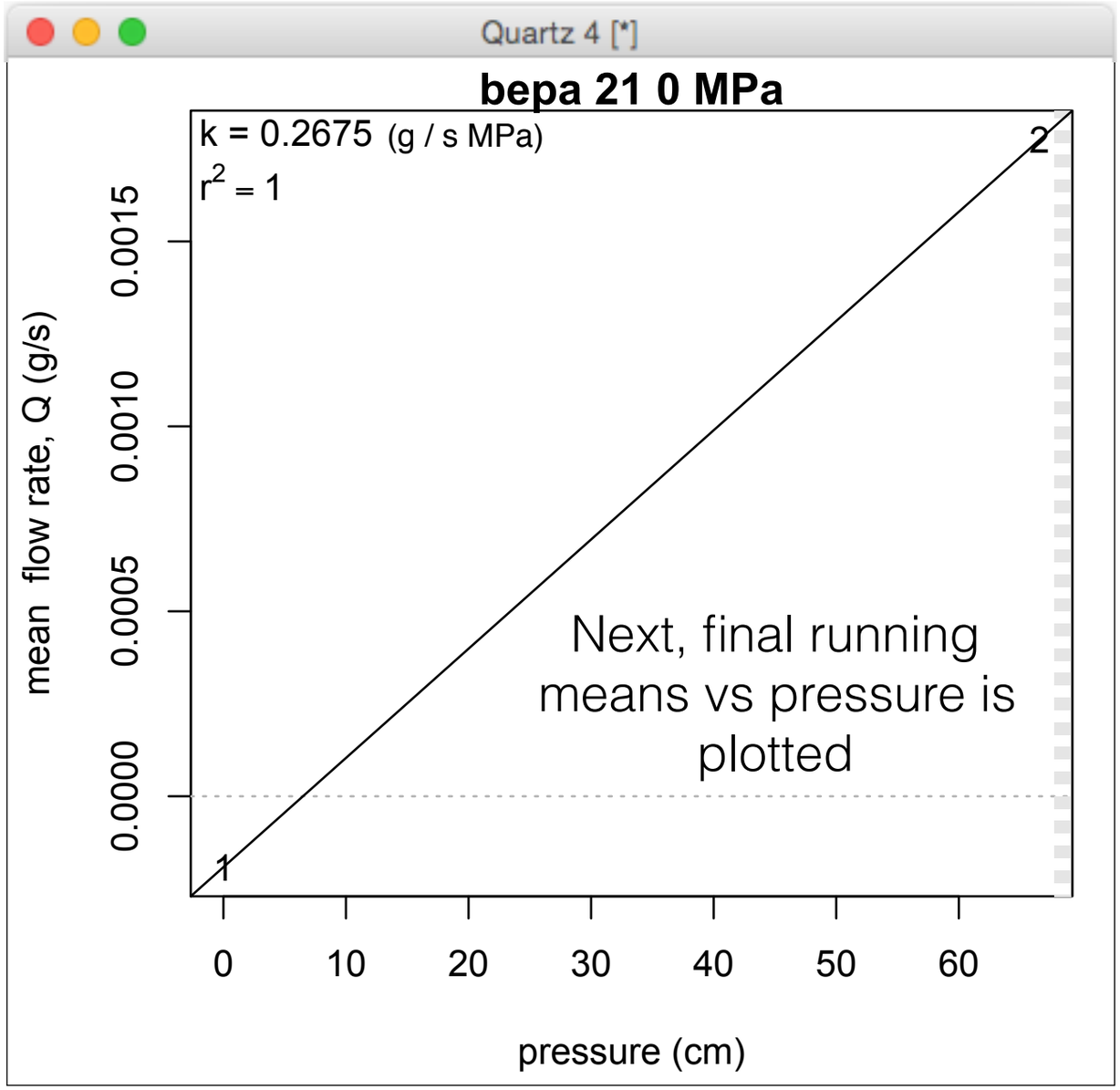
Making measurements with a balance

R Console

~/Desktop

Help Search

```
flowdata.csv to /users/duncan/desktop”
> cond(21,”bepa”,0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!”
which point to keep? (blank=last)
ending pressure? (cm) 66.6
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop”
“(go back one plot to see all mean flow
rates)”
```



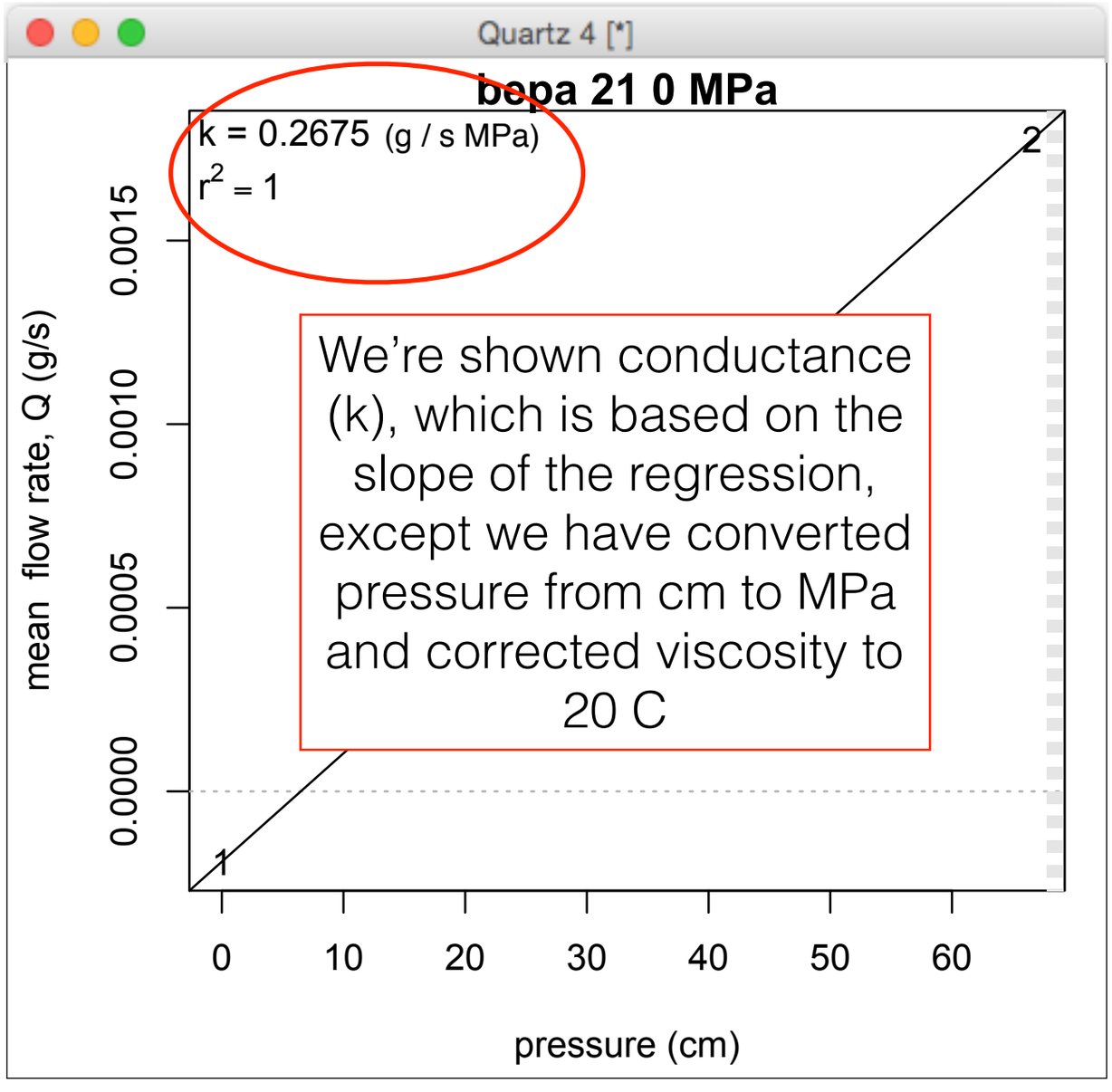
Making measurements with a balance

R Console

~/Desktop

Help Search

```
flowdata.csv to /users/duncan/desktop”
> cond(21,”bepa”,0)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!”
which point to keep? (blank=last)
ending pressure? (cm) 66.6
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop”
“(go back one plot to see all mean flow
rates)”
```



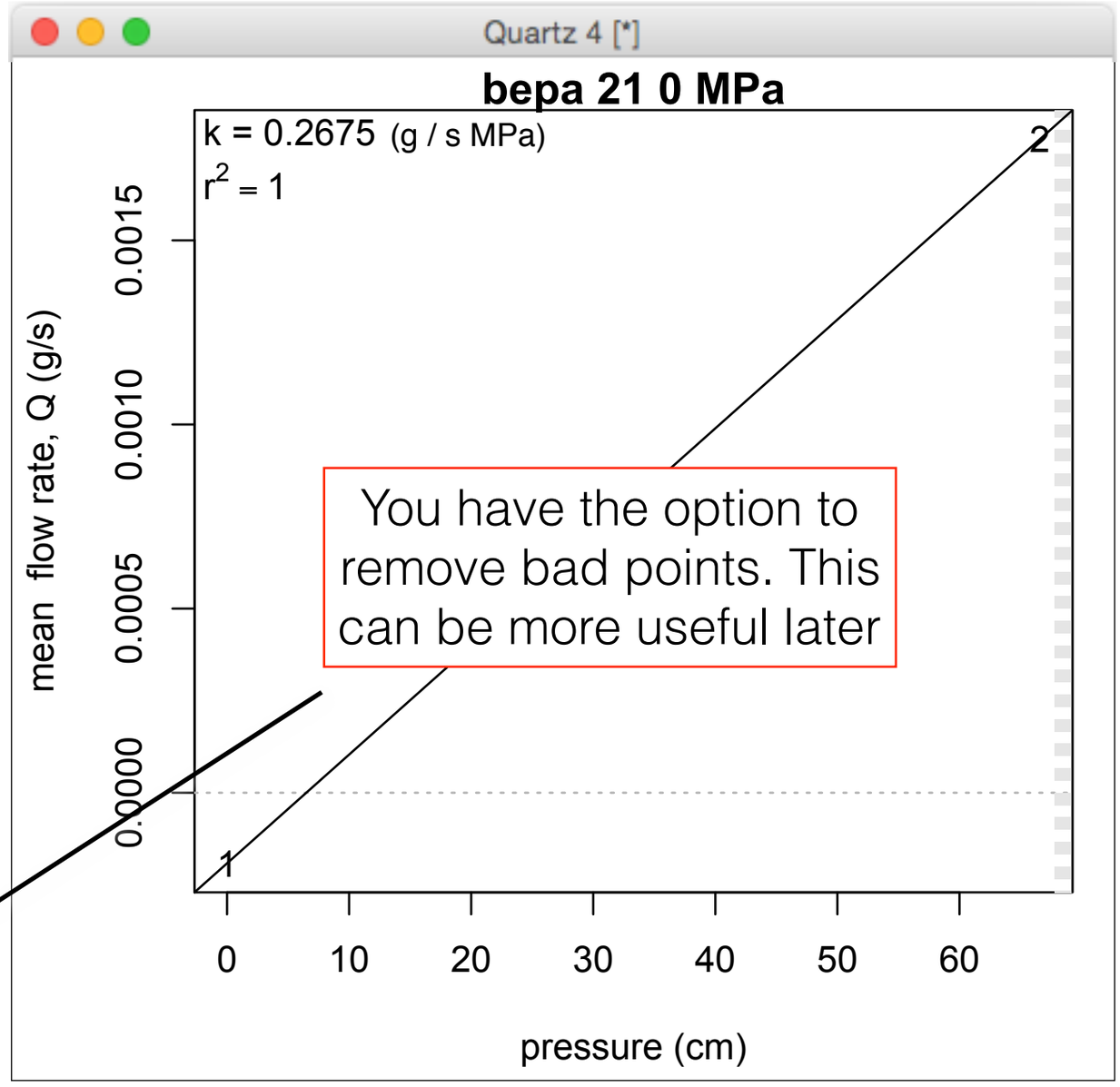
Making measurements with a balance

R Console

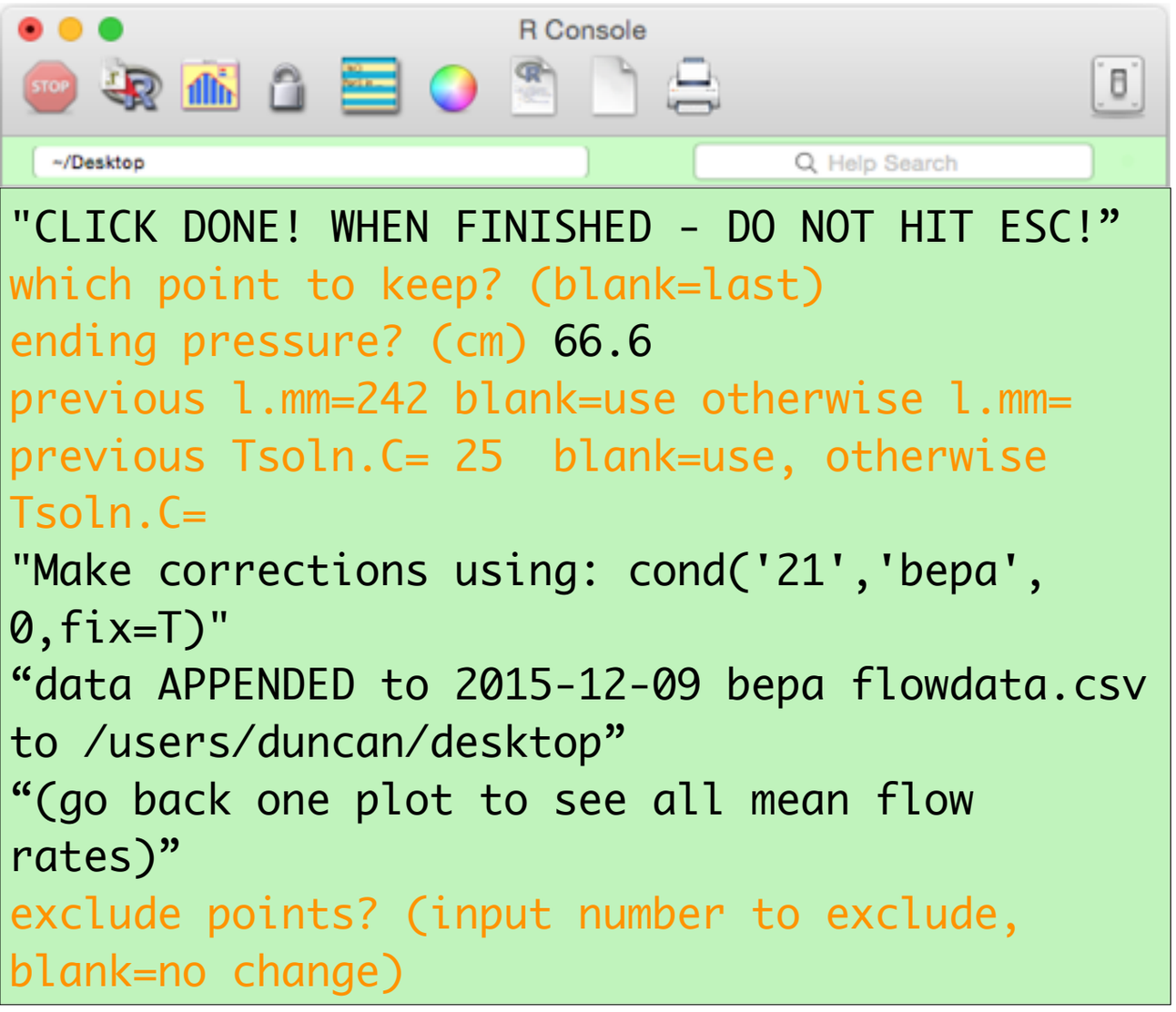
~/Desktop

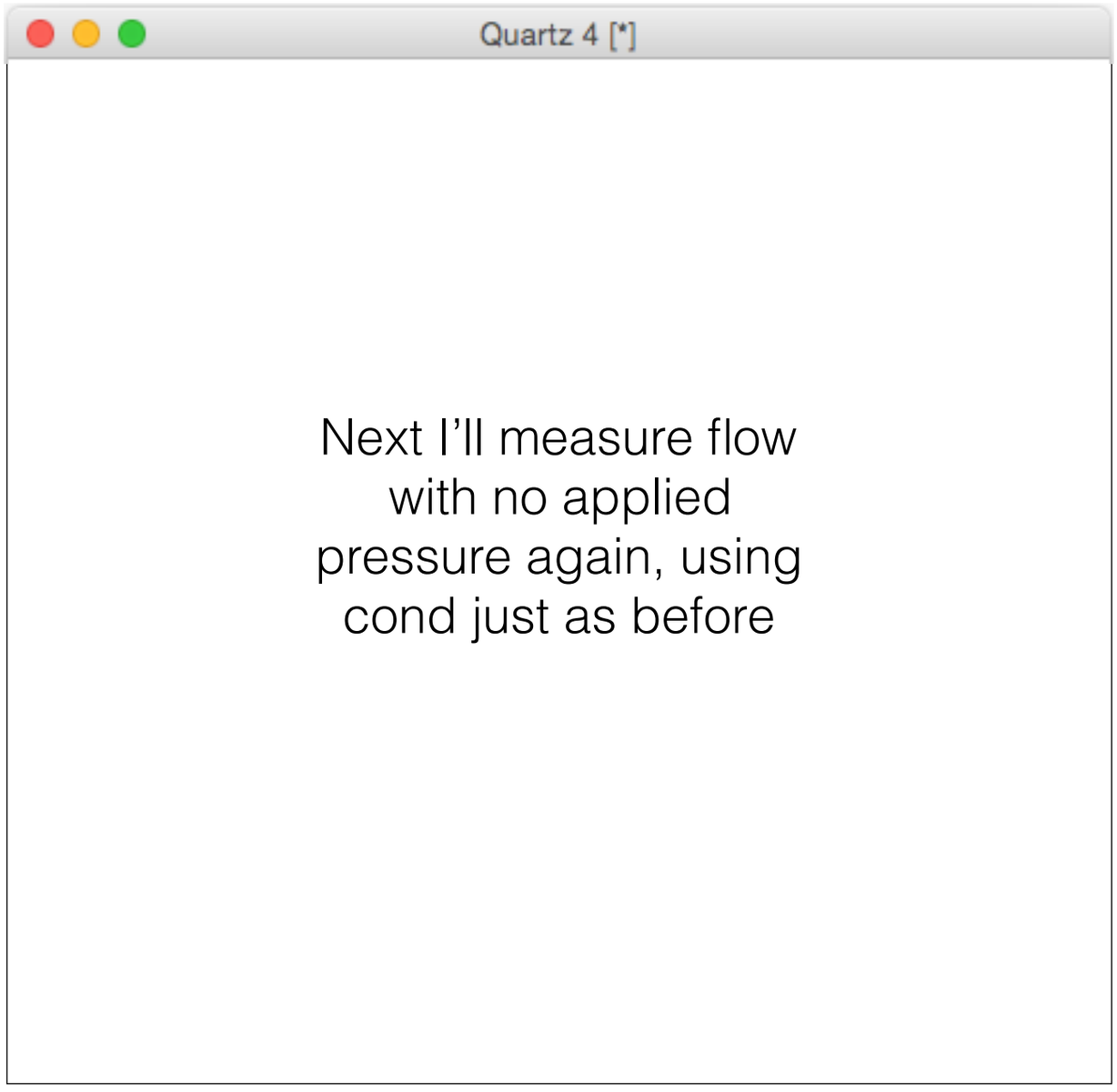
Help Search

```
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC!"
which point to keep? (blank=last)
ending pressure? (cm) 66.6
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop”
“(go back one plot to see all mean flow
rates)”
exclude points? (input number to exclude,
blank=no change)
```



Making measurements with a balance





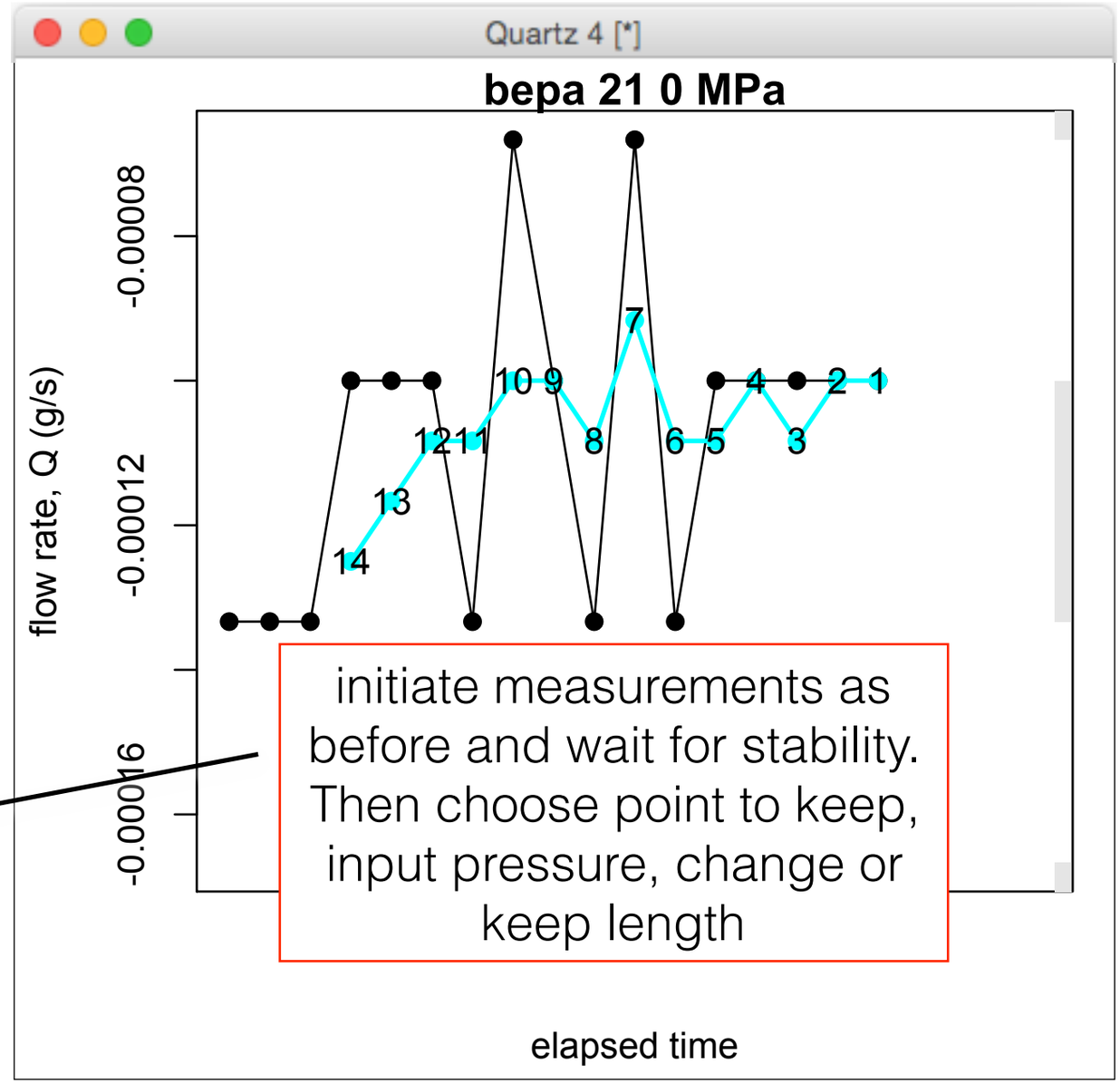
Making measurements with a balance

R Console

~/Desktop

Help Search

```
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop”
“(go back one plot to see all mean flow
rates)”
exclude points? (input number to exclude,
blank=no change)
> cond(21,”bepa”,0)
> “CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
```



initiate measurements as before and wait for stability. Then choose point to keep, input pressure, change or keep length

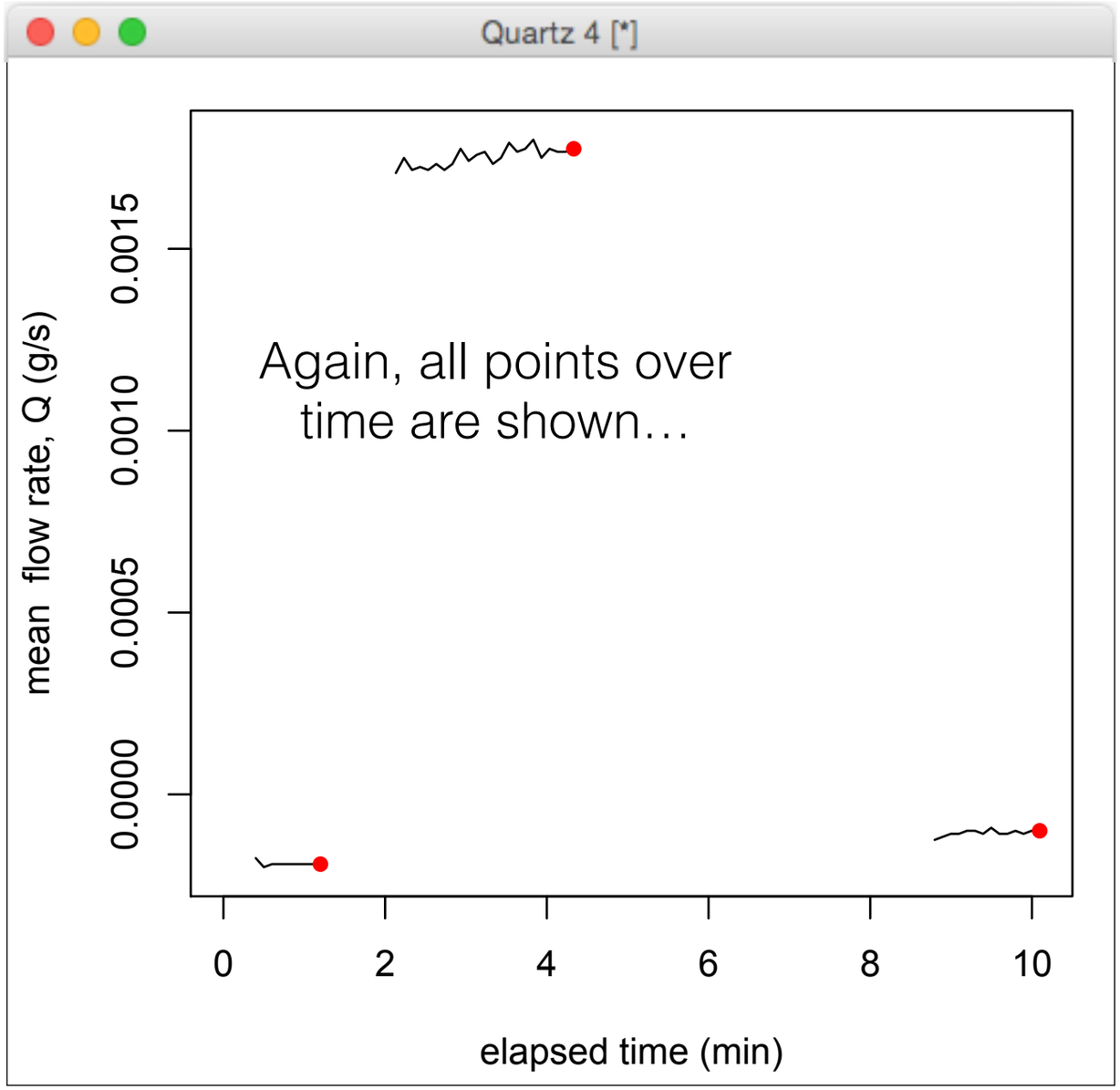
Making measurements with a balance

R Console

~/Desktop

Help Search

```
rates)"
exclude points? (input number to exclude,
blank=no change)
> cond(21,"bepa",0)
> "CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
"data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop"
```



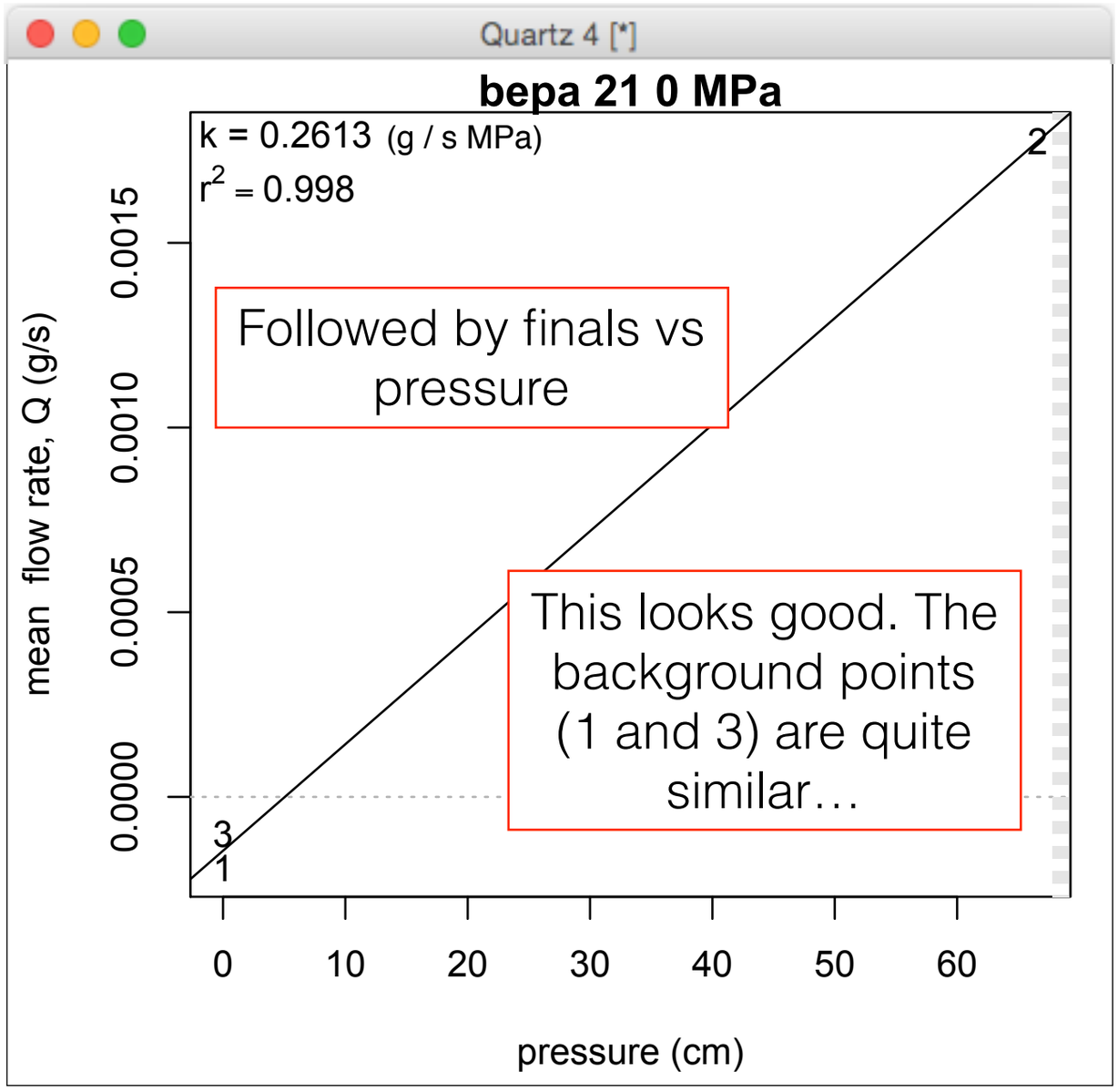
Making measurements with a balance

R Console

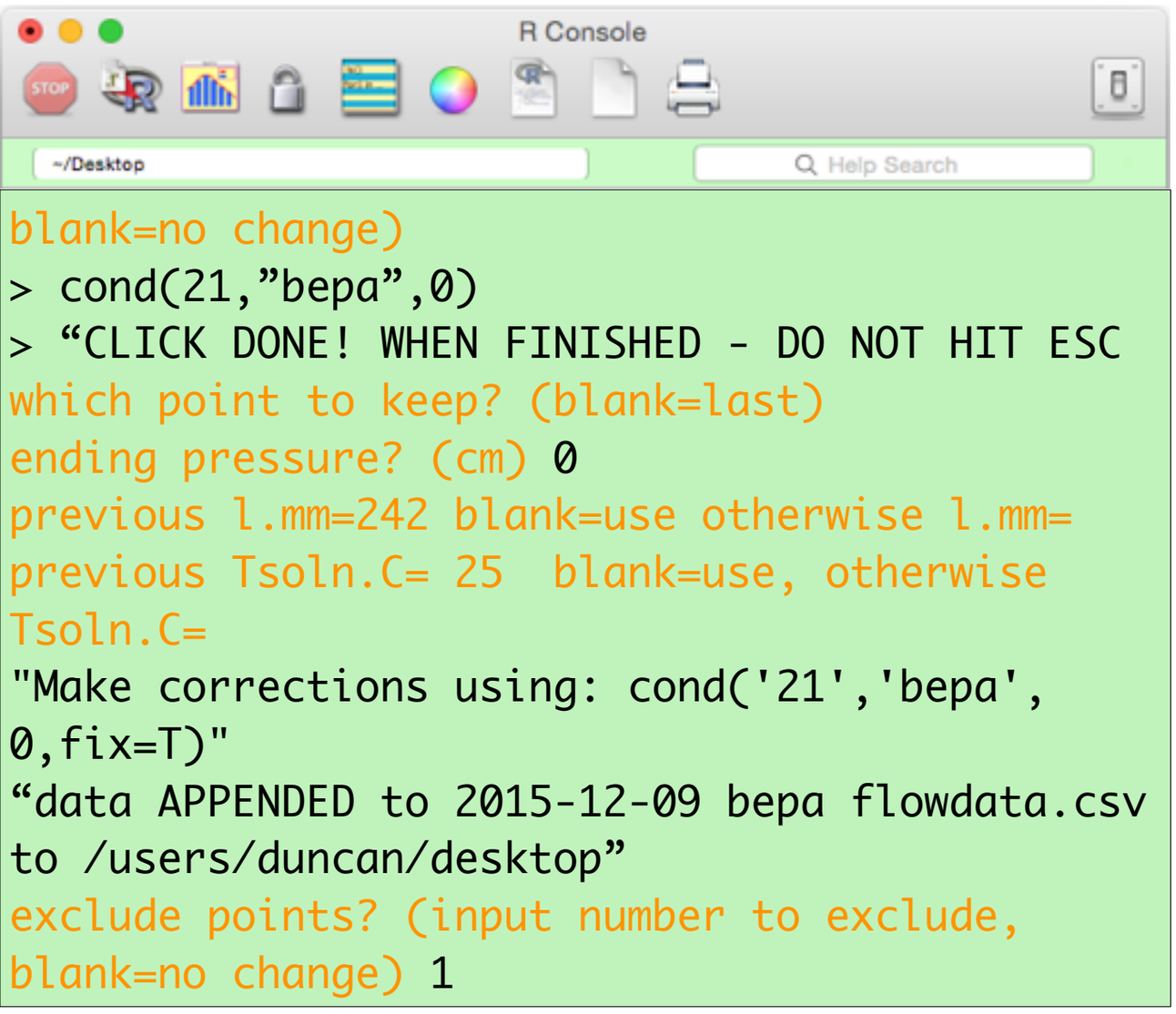
~/Desktop

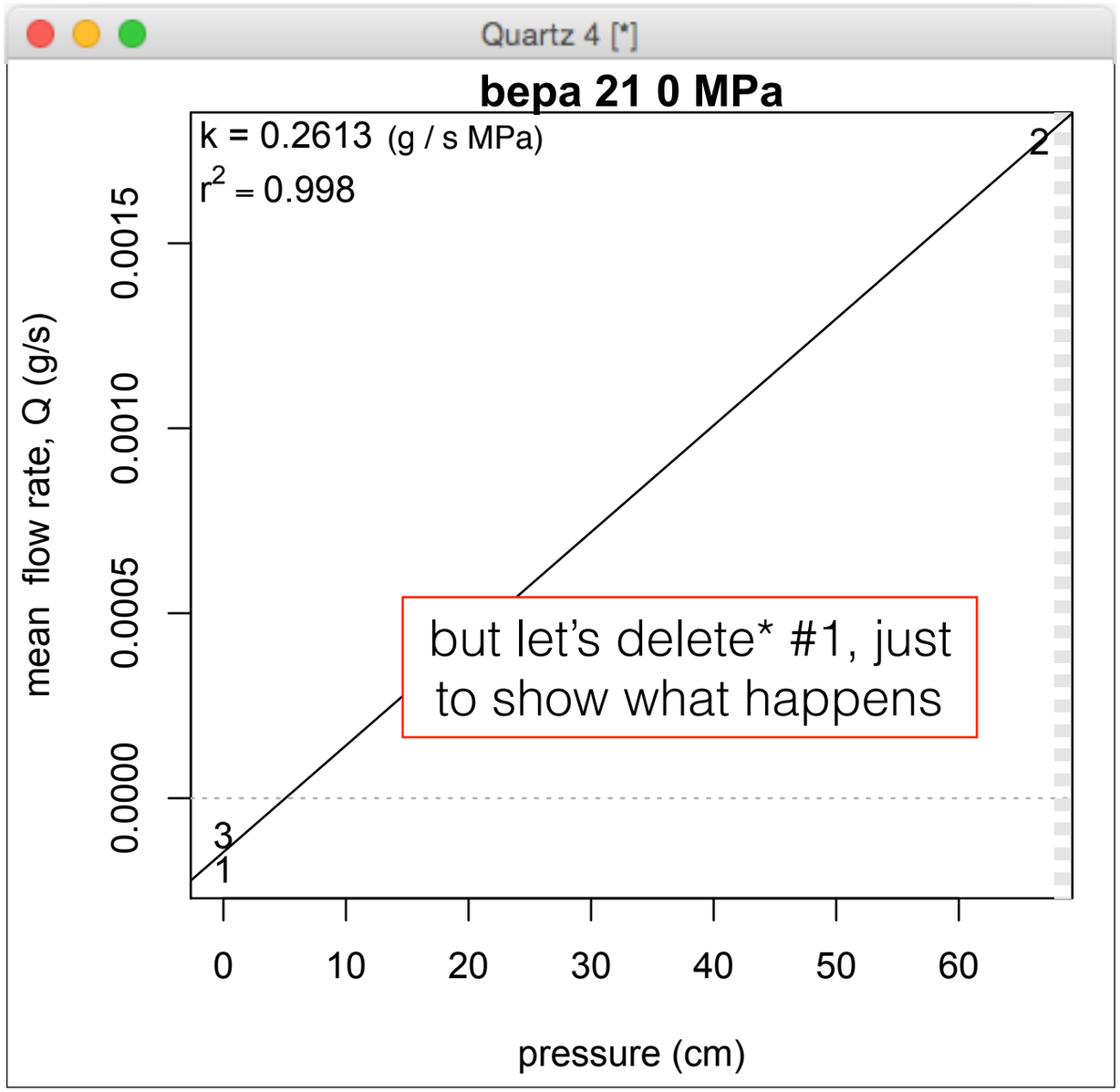
Help Search

```
blank=no change)
> cond(21,"bepa",0)
> "CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
"data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop"
exclude points? (input number to exclude,
blank=no change)
```



Making measurements with a balance





*don't worry, those data aren't really gone

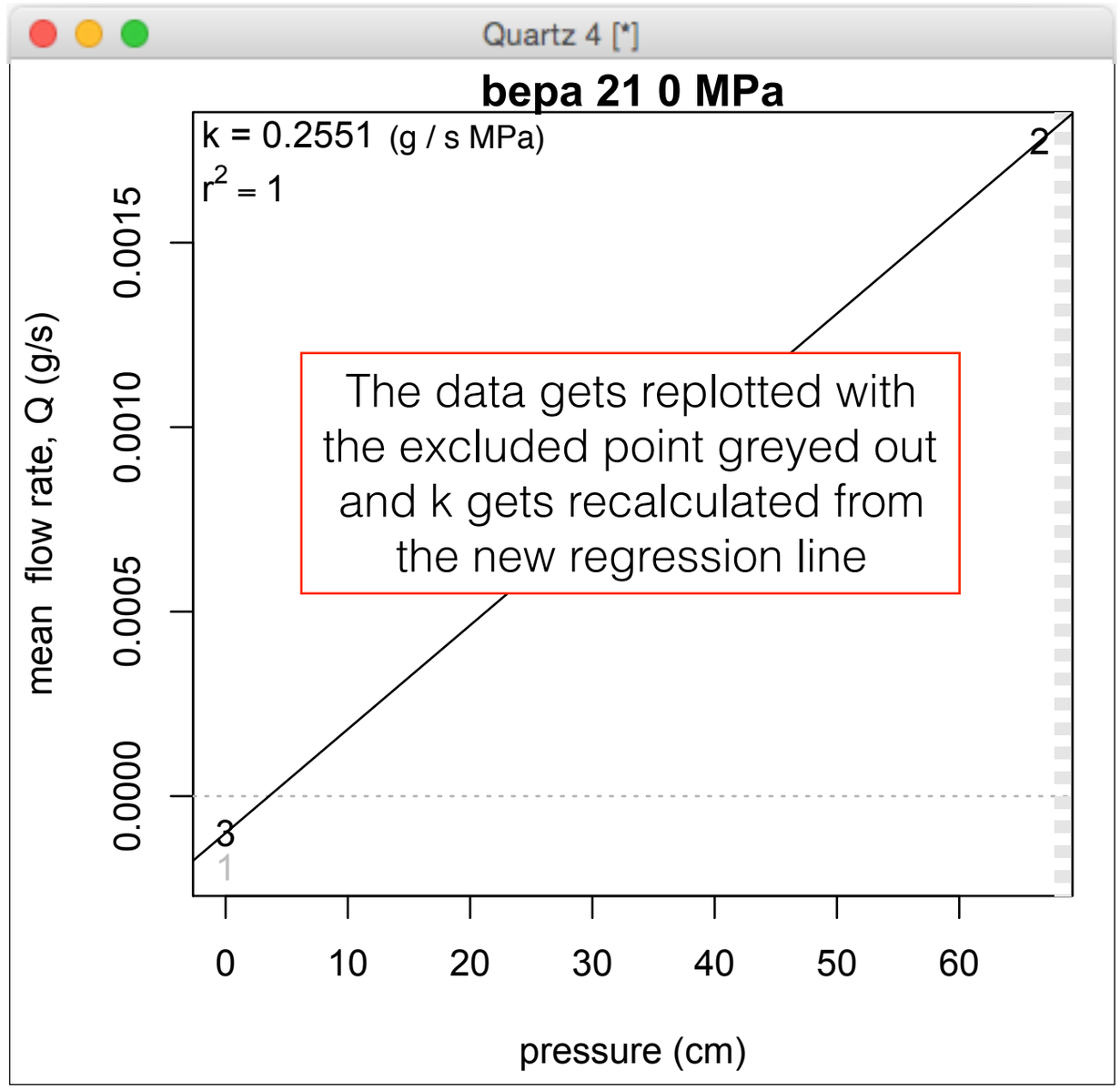
Making measurements with a balance

R Console

~/Desktop

Help Search

```
> “CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
ending pressure? (cm) 0
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
"data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop"
exclude points? (input number to exclude,
blank=no change) 1
exclude points? (input number to exclude,
blank=no change)
```



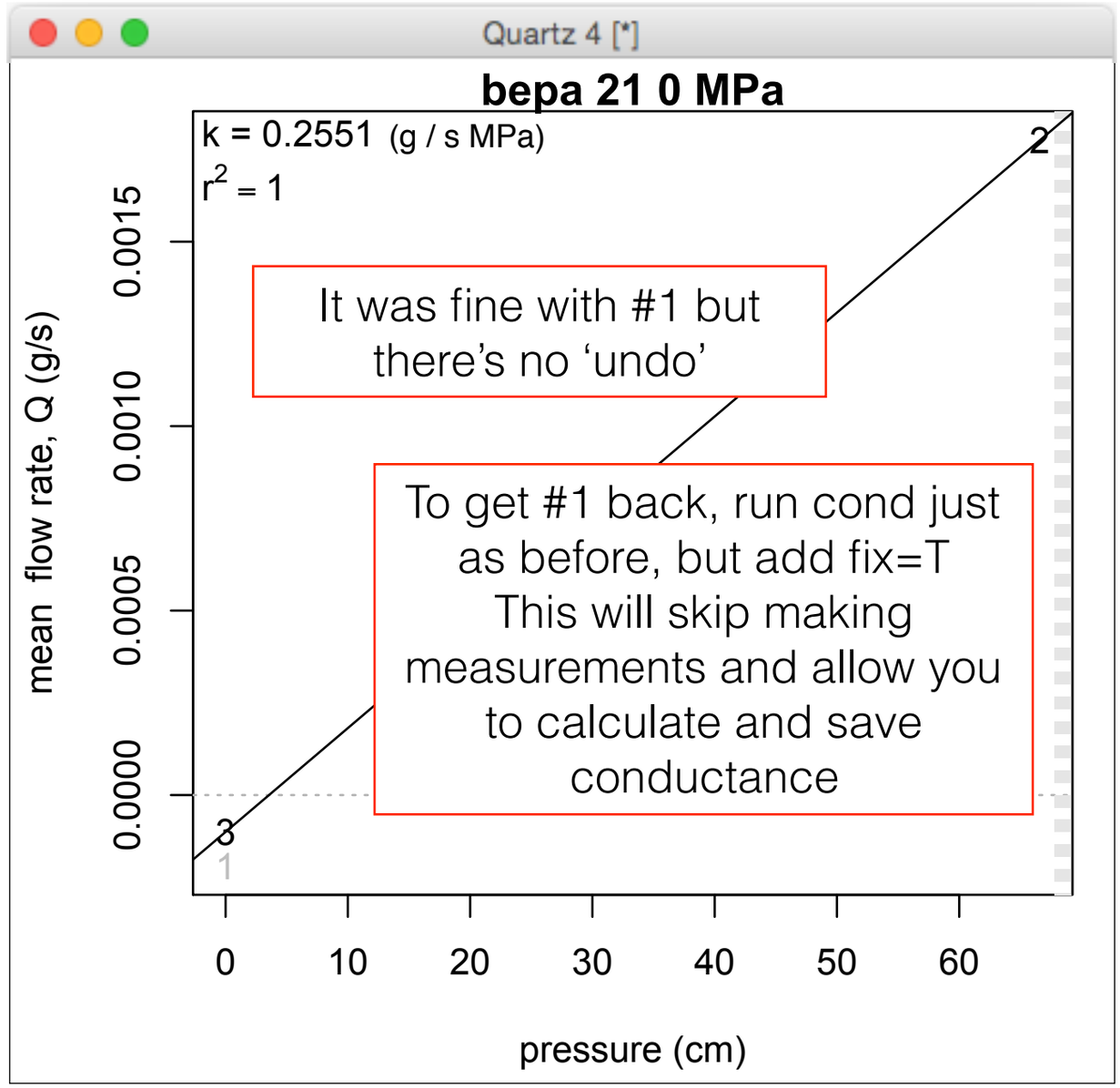
Making measurements with a balance

R Console

~/Desktop

Help Search

```
which point to keep? (blank=last)
ending pressure? (cm) 0
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
"data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop"
exclude points? (input number to exclude,
blank=no change) 1
exclude points? (input number to exclude,
blank=no change)
> cond(21,"bepa",0,fix=T)
```



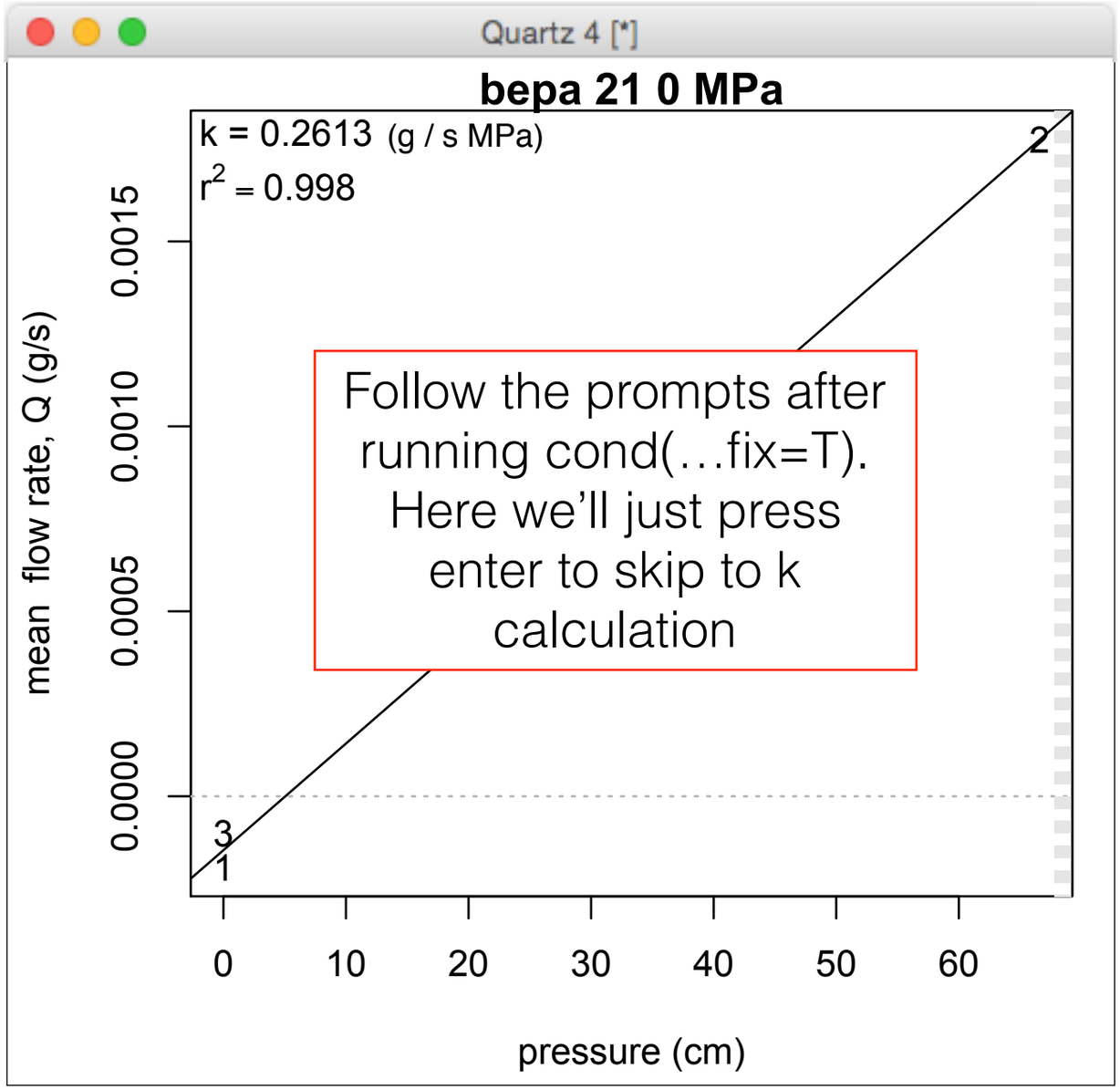
Making measurements with a balance

R Console

~/Desktop

Help Search

```
previous l.mm=242 blank=use otherwise l.mm=
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('21','bepa',
0,fix=T)"
“data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop”
exclude points? (input number to exclude,
blank=no change) 1
exclude points? (input number to exclude,
blank=no change)
> cond(21,”bepa”,0,fix=T)
which measure to fix (blank=skip to k
calculation):  1, 2, 3 ?
```



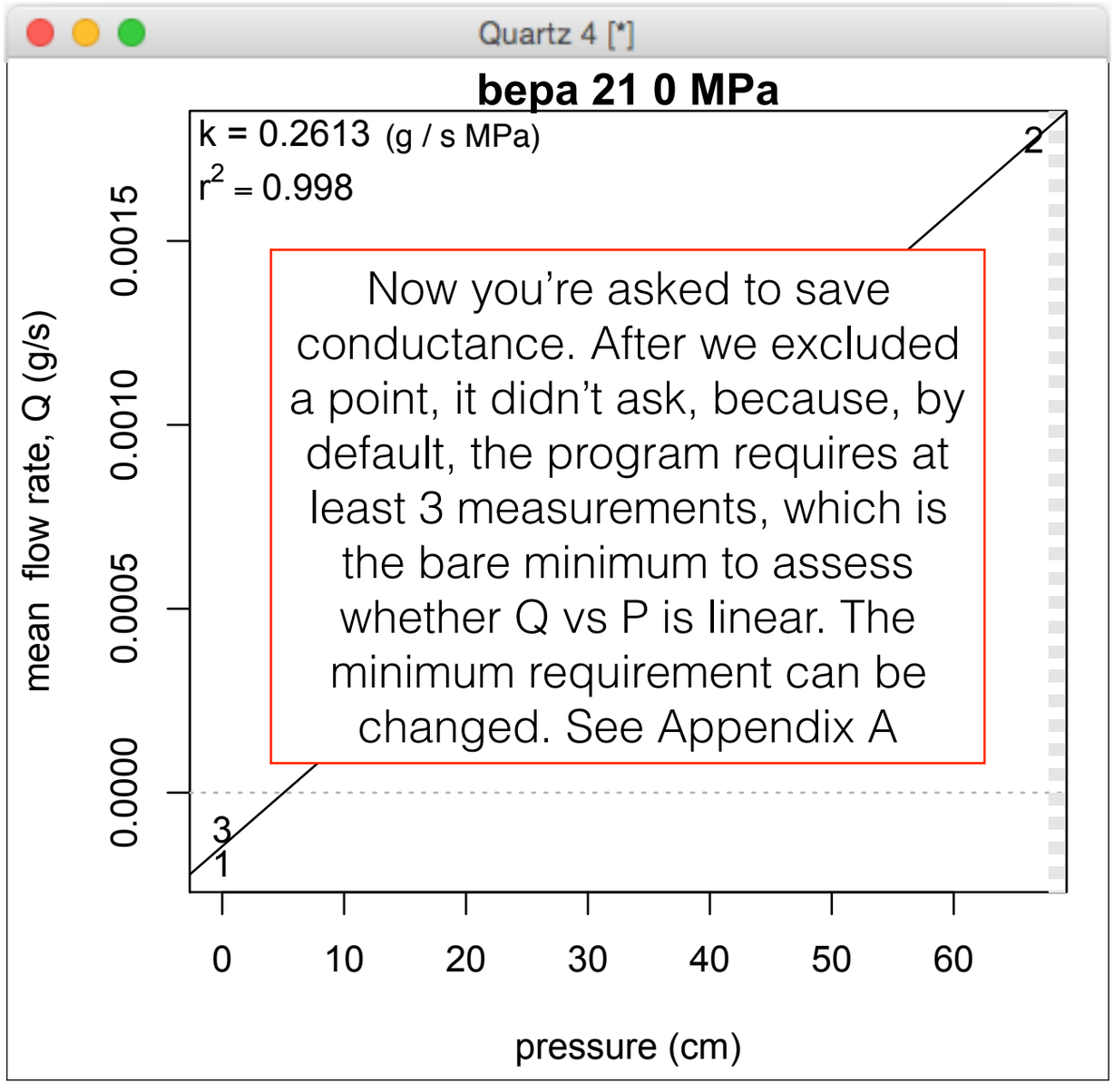
Making measurements with a balance

R Console

~/Desktop

Help Search

```
"data APPENDED to 2015-12-09 bepa flowdata.csv
to /users/duncan/desktop"
exclude points? (input number to exclude,
blank=no change) 1
exclude points? (input number to exclude,
blank=no change)
> cond(21,"bepa",0,fix=T)
which measure to fix (blank=skip to k
calculation):  1, 2, 3 ?
"(go back one plot to see all mean flow
rates)"
exclude points? (input number to exclude,
blank=no change)
save conductance? (y=yes blank=no) y
```



Making measurements with a balance

R Console

~/Desktop

Help Search

```
which measure to fix (blank=skip to k
calculation):  1, 2, 3 ?
“(go back one plot to see all mean flow
rates)”
exclude points? (input number to exclude,
blank=no change)
save conductance? (y=yes blank=no) y
“data written in NEW file as: 2015-12-09 bepa
condcalc.csv to /users/duncan/desktop”
     t.day   sp numbr  P.MPa          nomID    stemID  l.mm
1  343.436 bepa    21      0  bepa 21 0 MPa   bepa 21   242
    d.mm  k.g.s.MPa         r2  K.g.mm.s.MPa
1    5.2  0.261289  0.9982949      63.231945
Ks.g.s.MPa.mm  plc
1     2.97741    0
```

Quartz 4 [*]

Conductance calculations are saved in a new “condcalc.csv” file in your working directory and the program shows you all data within that file

saved conductances and conductivities are standardized to 20 C.

Making measurements with a balance

The saved condcalc.csv file looks like this

t.day	sp	numbr	P.MPa	nomID	stemID	l.mm	d.mm	k.g.s.MPa	r2
293.6752091213	beoc	3		0 beoc 3 0 MPa	beoc 3	243	5.6	0.1002898723	0.9999260117
293.6986659103	beoc	5		0 beoc 5 0 MPa	beoc 5	244	4.4	0.0791783257	0.9994449661
293.7221226993	beoc	6		0 beoc 6 0 MPa	beoc 6	245	5.6	0.1015599096	0.999914944
293.7455794883	beoc	7		0 beoc 7 0 MPa	beoc 7	241	4.7	0.0922087384	0.9998961259
293.7690362773	beoc	9		0 beoc 9 0 MPa	beoc 9	244	5.6	0.1269076781	0.9999999993
293.7924930663	beoc	10		0 beoc 10 0 MPa	beoc 10	245	5.6	0.1159782108	0.9997277468

time (decimal day) final measurement was completed

species (or other group name)

individual number

treatment pressure

stem ID and treatment (used by program for grouping)

species and number (used by program for grouping)

stem length

stem diameter

conductance g / (s MPa) corrected to 20 C

r-squared of conductance regression

continued…

Making measurements with a balance

The saved condcalc.csv file looks like this

K.g.mm.s.MPa	Ks.g.s.MPa.mm	ver	plc	
24.3704389768	0.989458119	v18		0
19.3195114752	1.27057675	v18		0
24.8821778534	1.010235102	v18		0
22.2223059563	1.28086549	v18		0
30.9654734544	1.257221470	v18		0
28.4146616547	1.153656596	v18		0

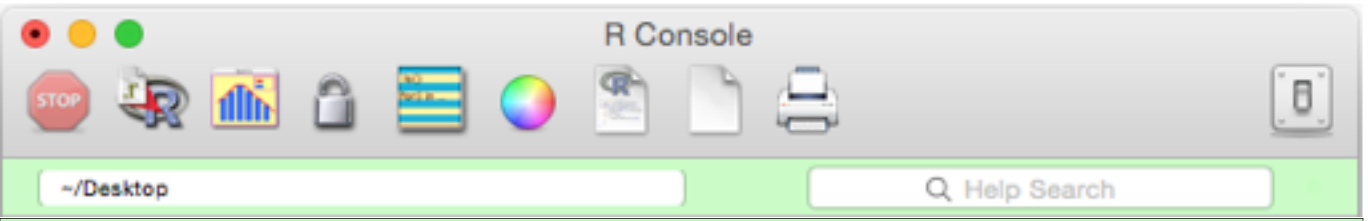
conductivity
(g mm) / (s MPa)
corrected to 20 C

stem-area specific
conductivity
g / (s MPa mm)
corrected to 20 C

conductR
version

percent loss
conductivity, using
K at most
favorable
treatment pressure
as maximum K.

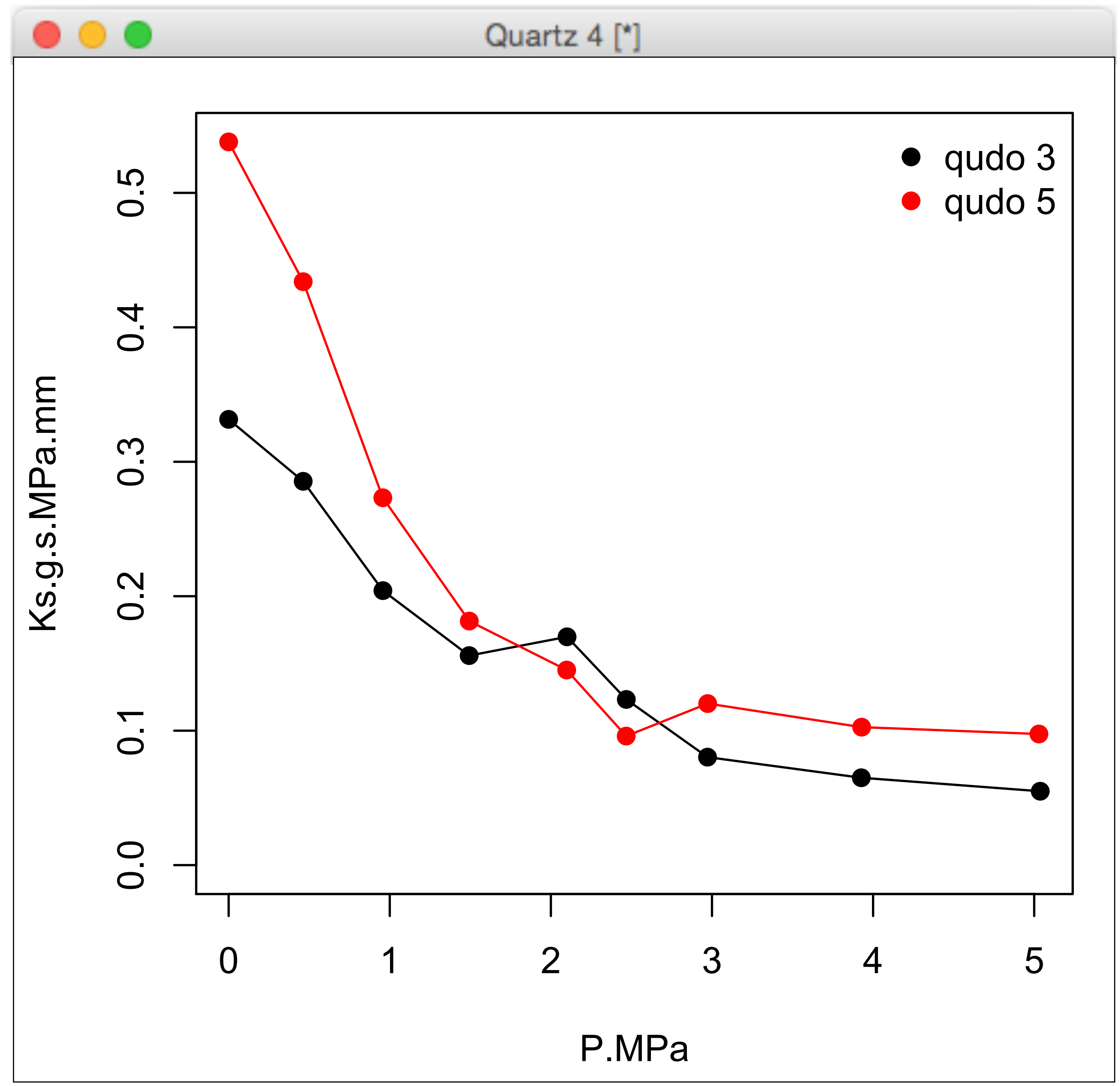
Viewing vulnerability



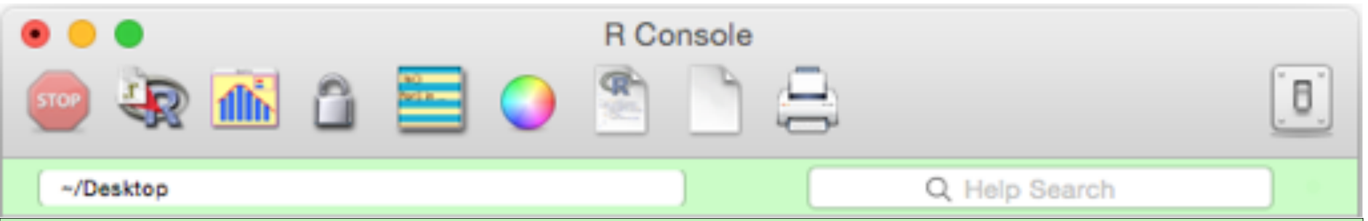

```
>
>
>
>
>
>
>
>
>
>
>
>
>
> showvuln(“qudo")
```

if constructing a vulnerability curve, the showvuln function plots all data in condcalc.csv for the specified species (note this is qudo not bepa)

Ks is plotted by default (see Appendix A)

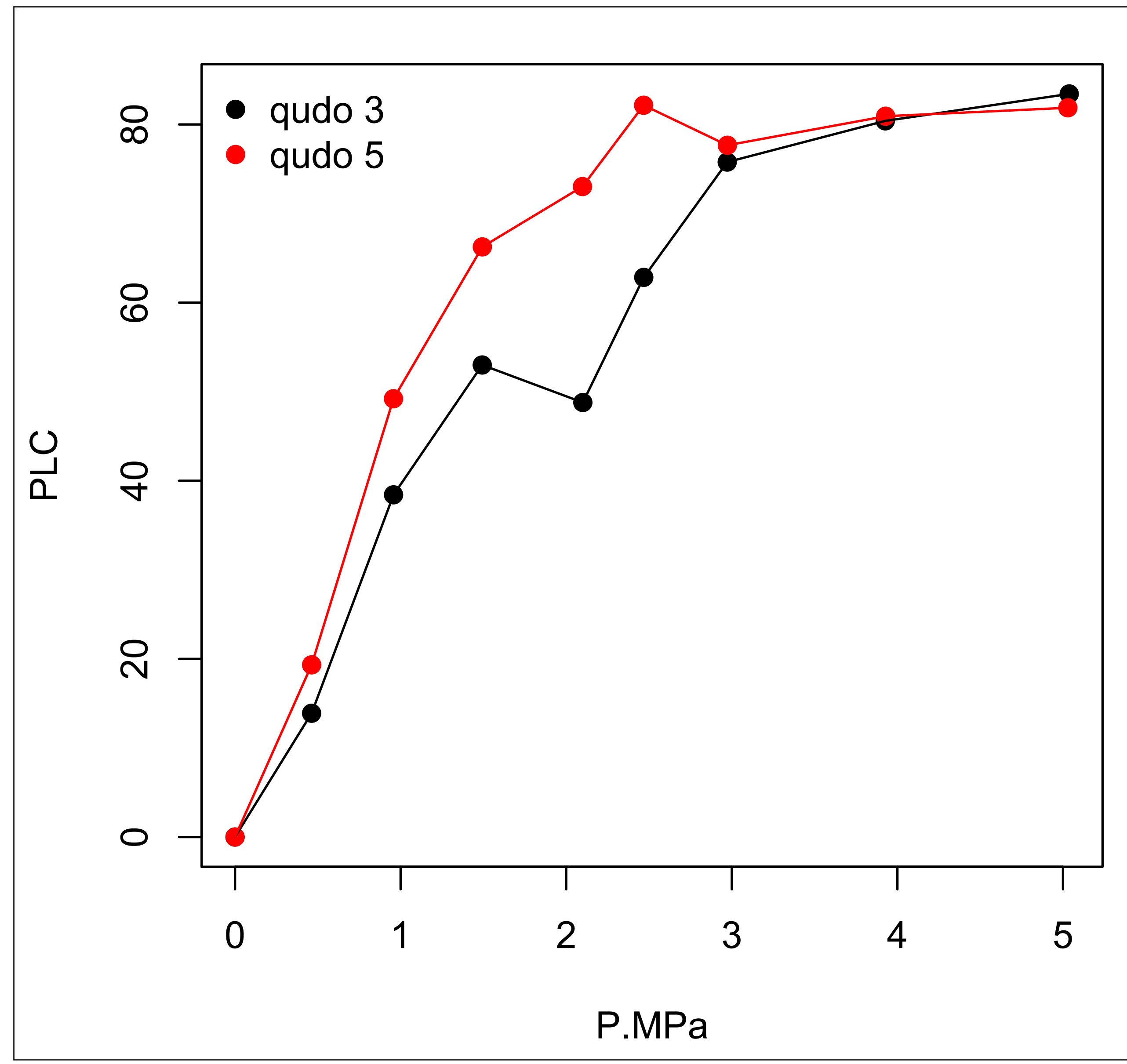


Viewing vulnerability



plotting PLC is another option (see Appendix A for more options)

```
>
>
>
>
>
>
>
>
>
>
>
>
> showvuln(“qudo)
> showvuln(“qudo”,as.plc=T)
```

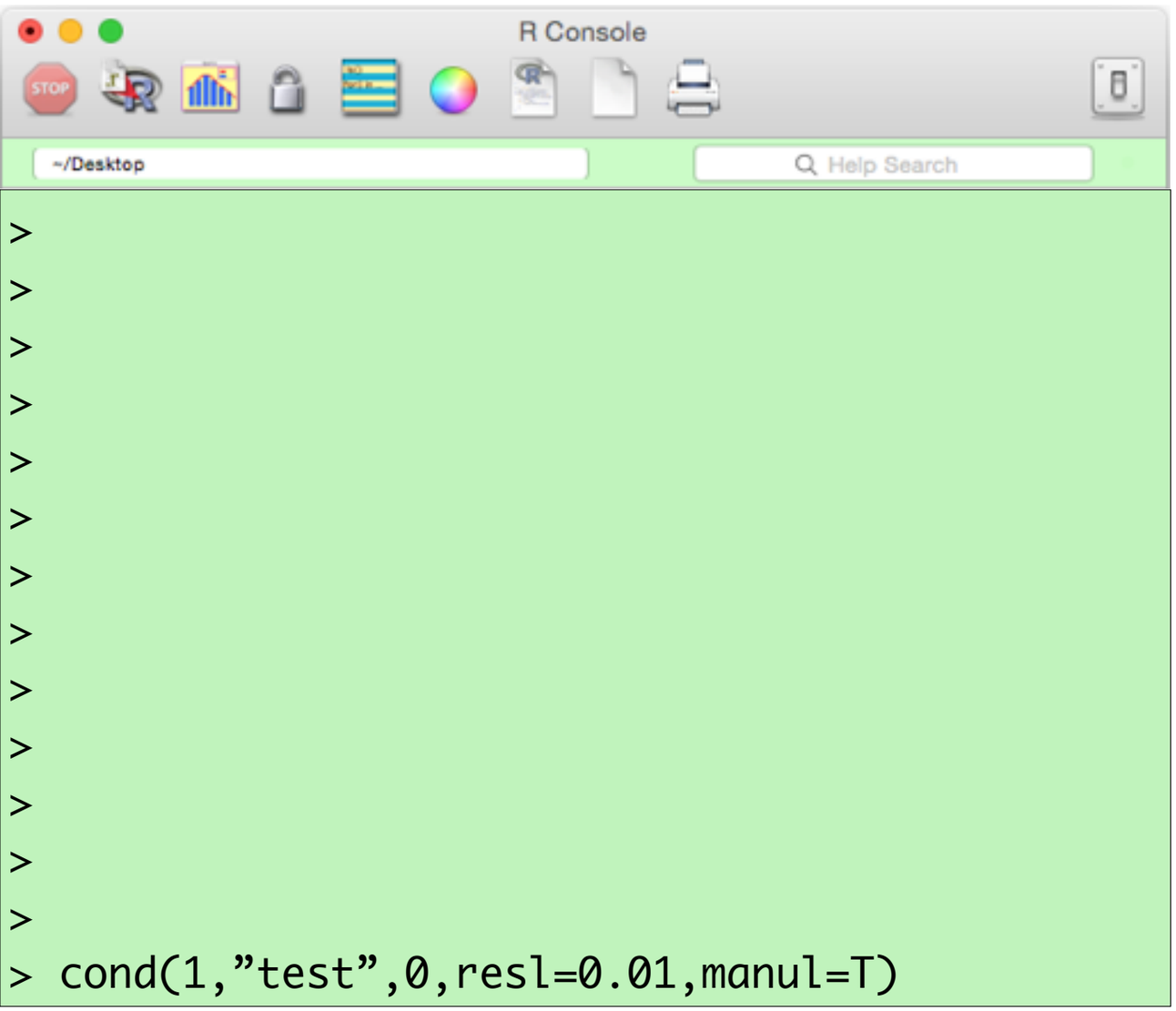


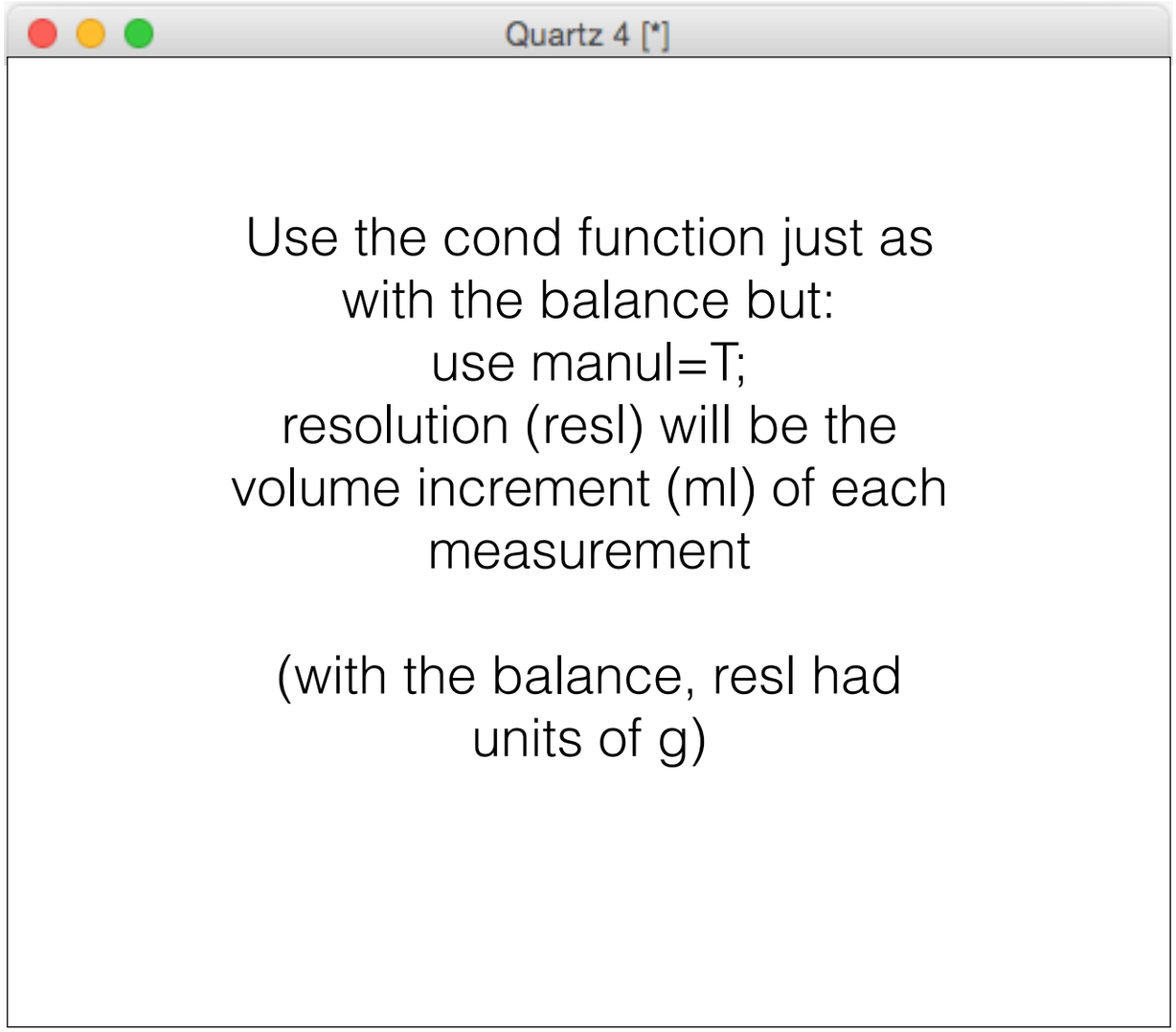
Measurements with a pipette: manual mode

Most details of the program are the same except you control the measurements:

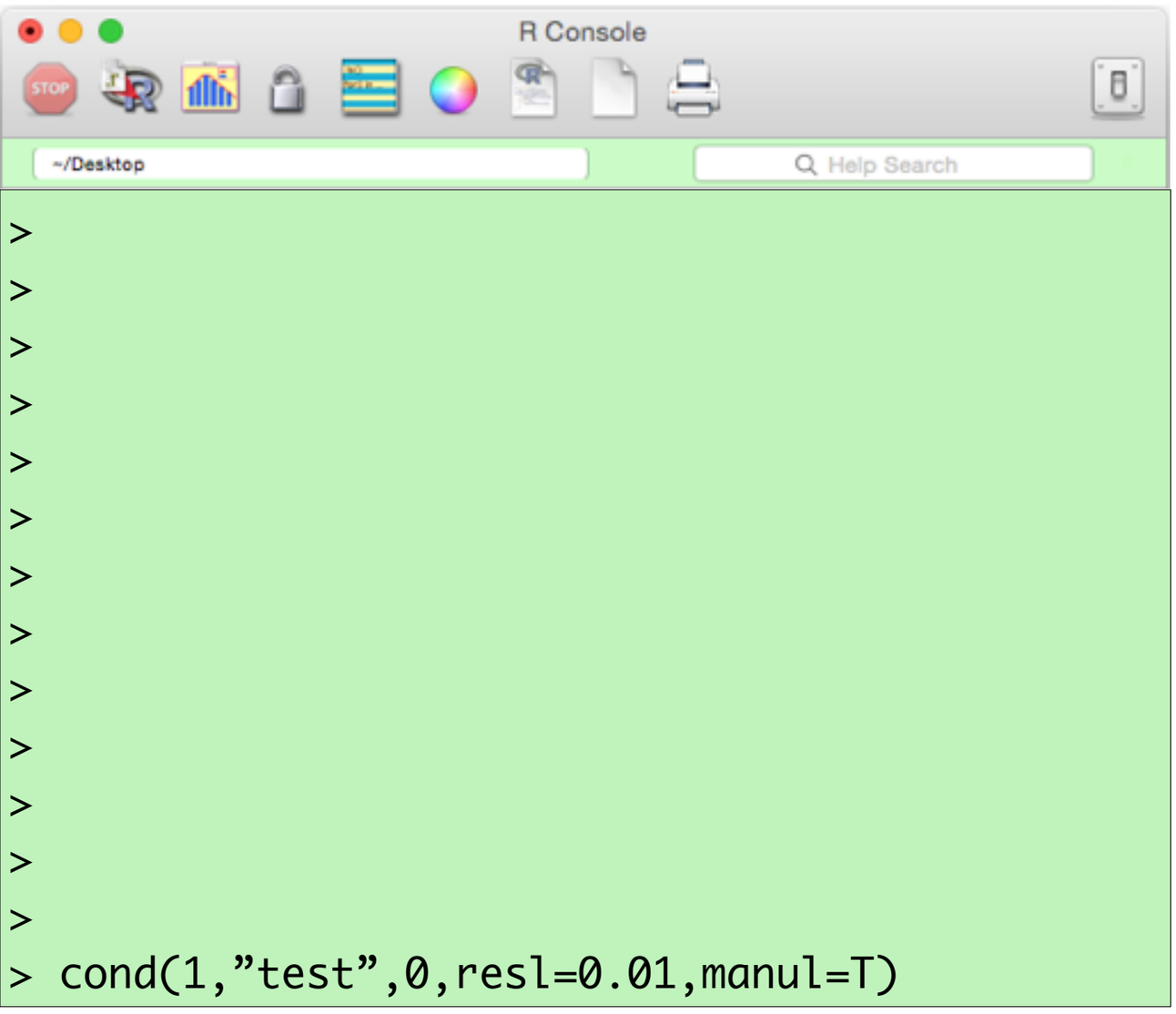
Instead of the program measuring change at fixed times, you tell the program when a fixed unit of liquid has moved into (or out of) the xylem

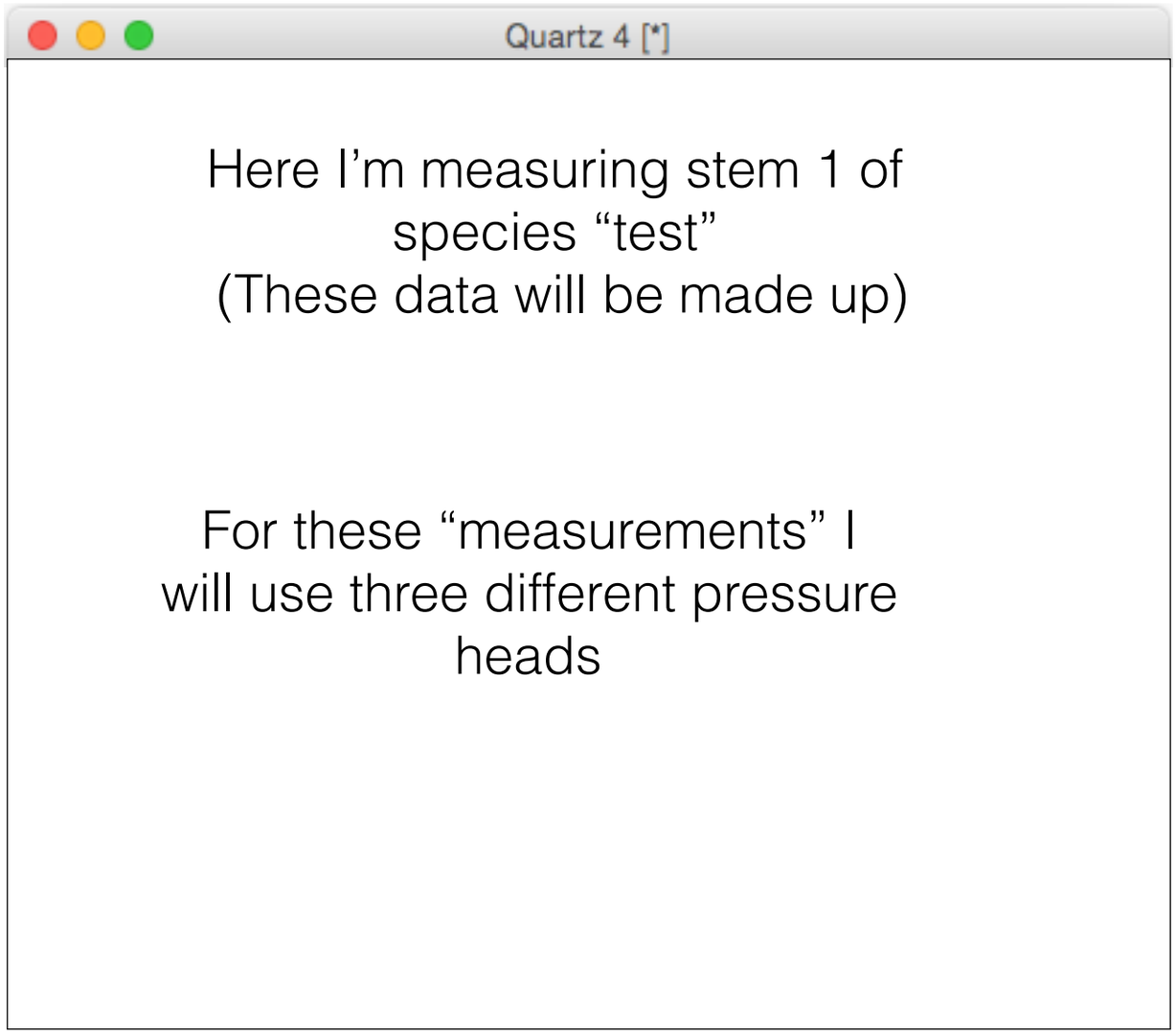
Making measurements with a pipette



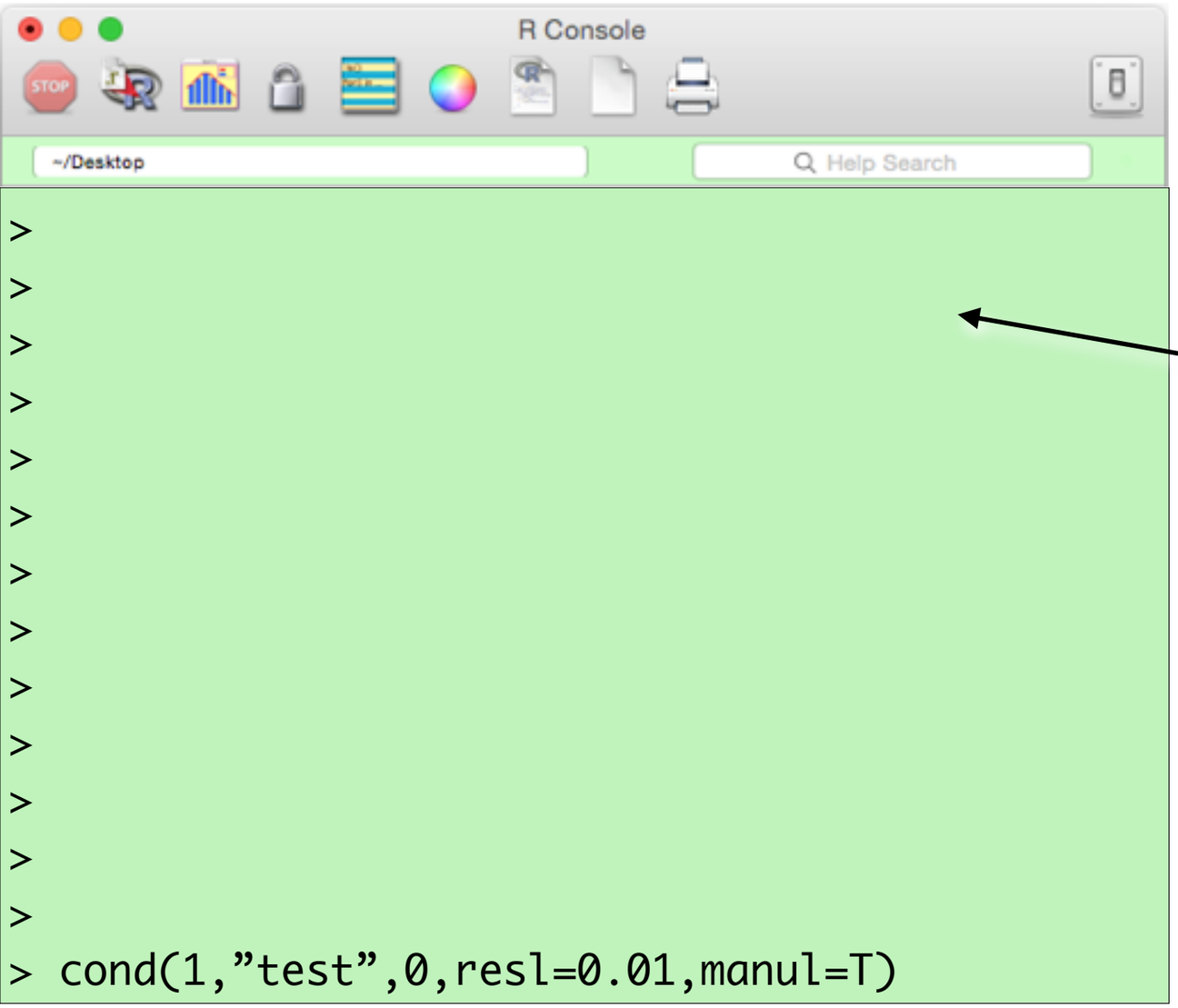


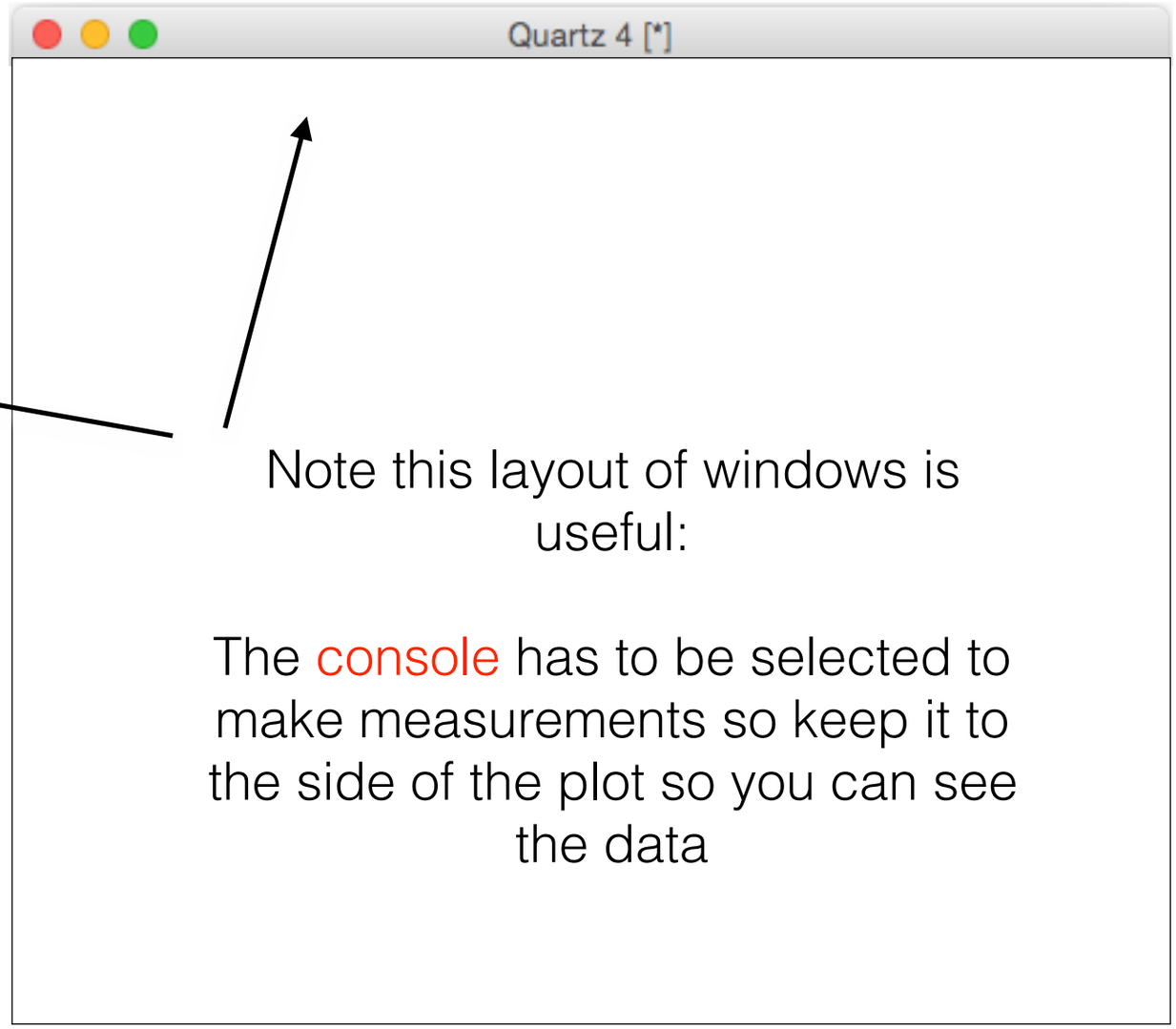
Making measurements with a pipette



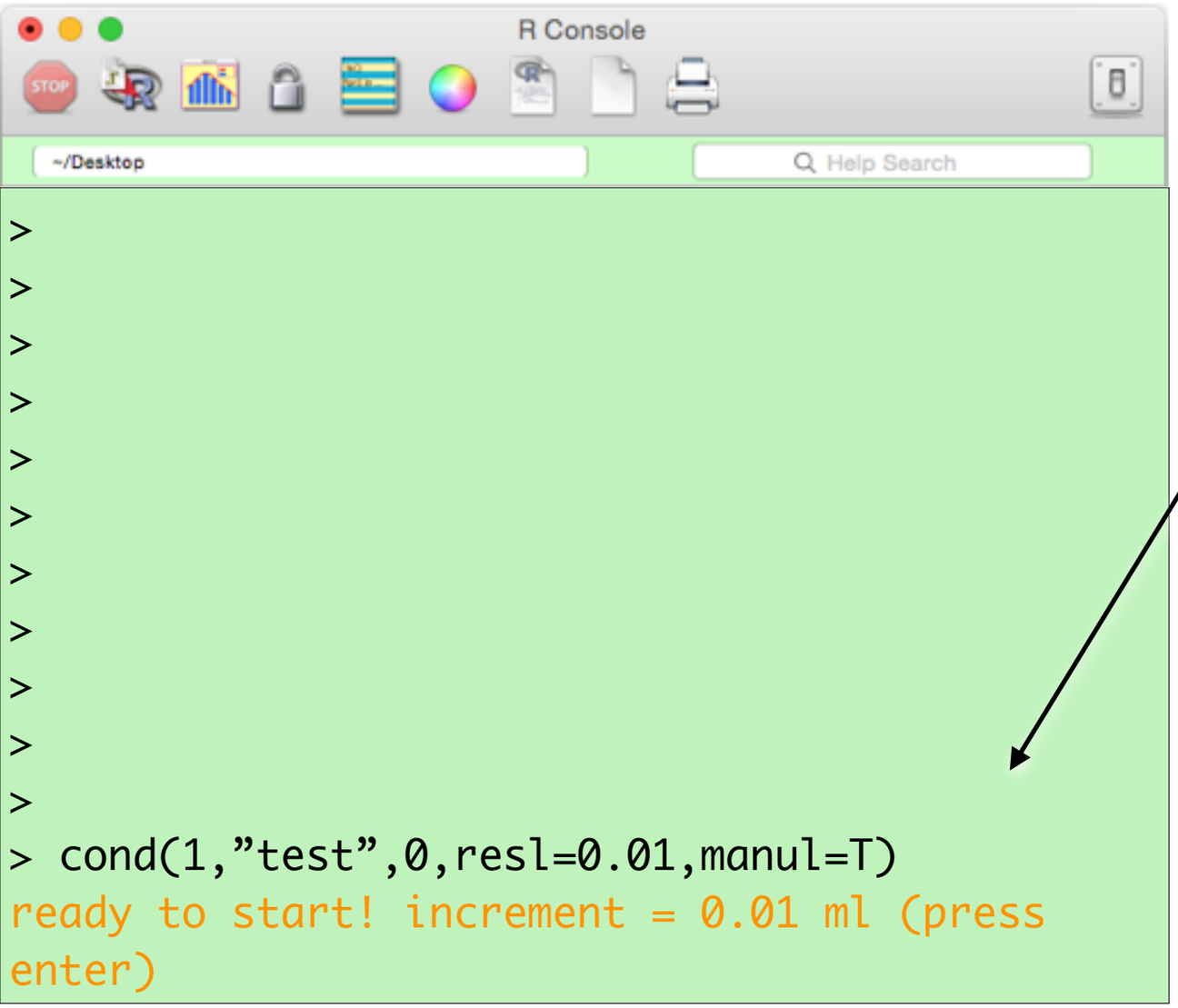


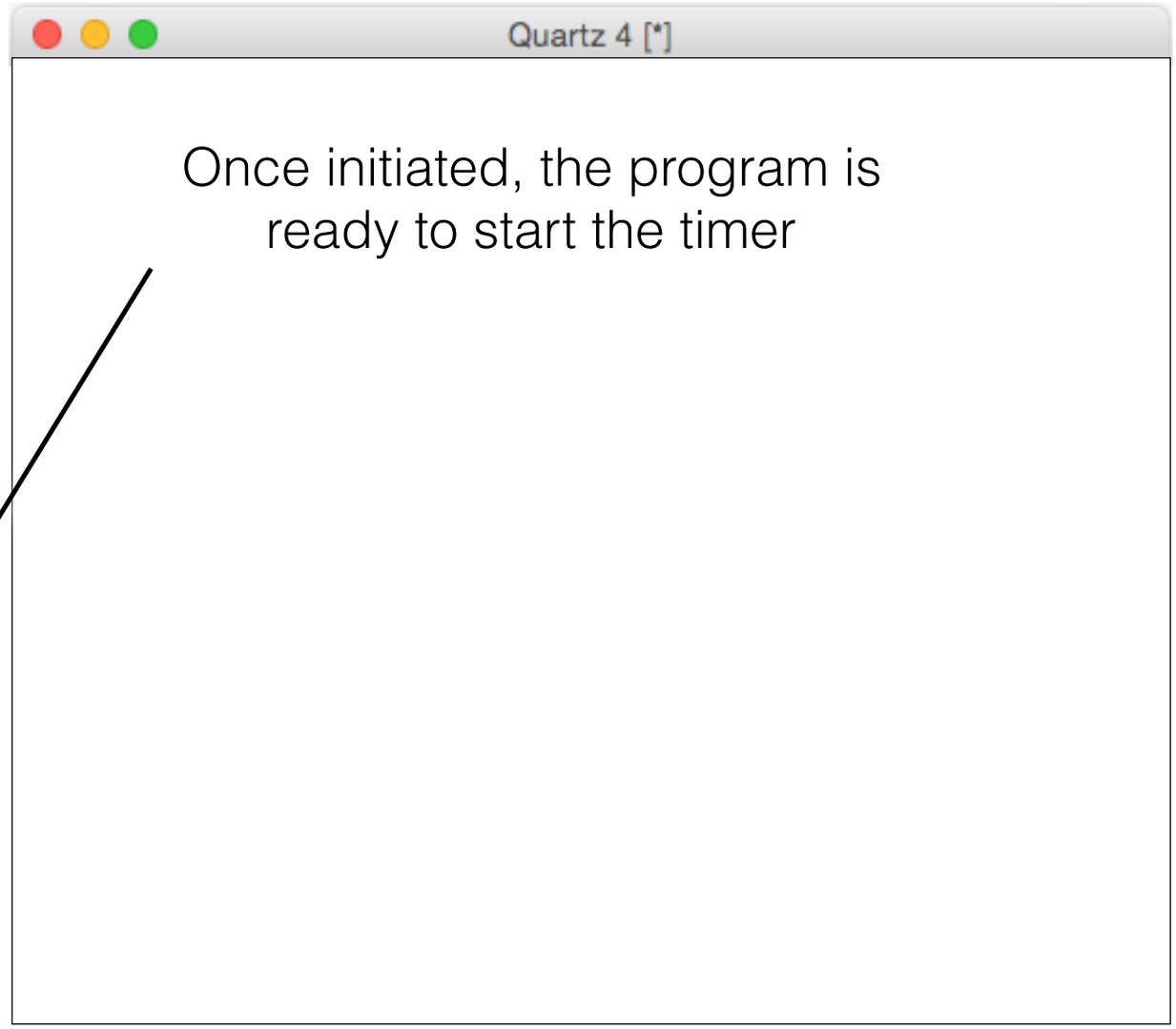
Making measurements with a pipette





Making measurements with a pipette





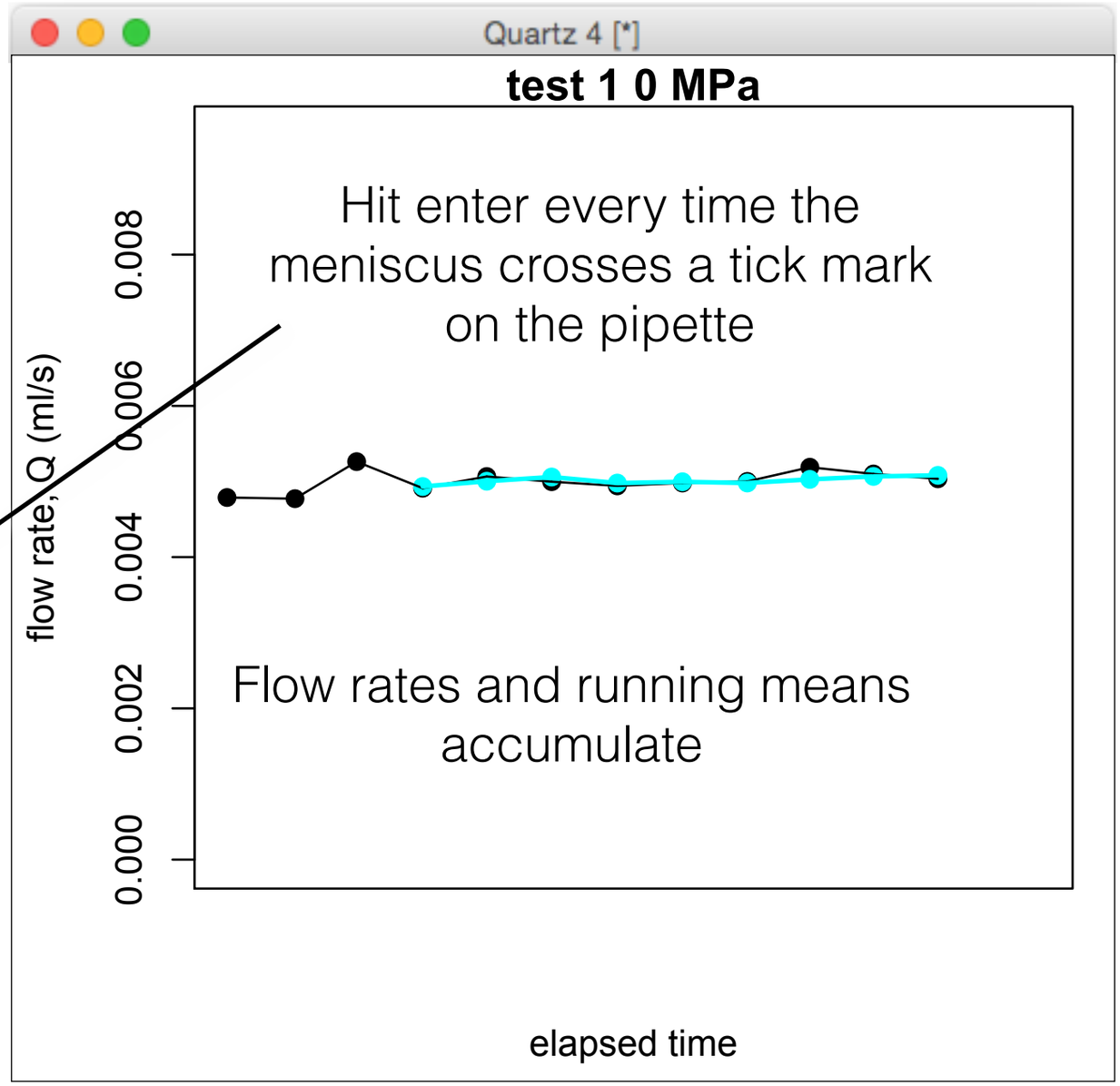
Making measurements with a pipette

R Console

~/Desktop

Help Search

```
>
> cond(1,"test",0,resl=0.01,manul=T)
ready to start! increment = 0.01 ml (press
enter)
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
```



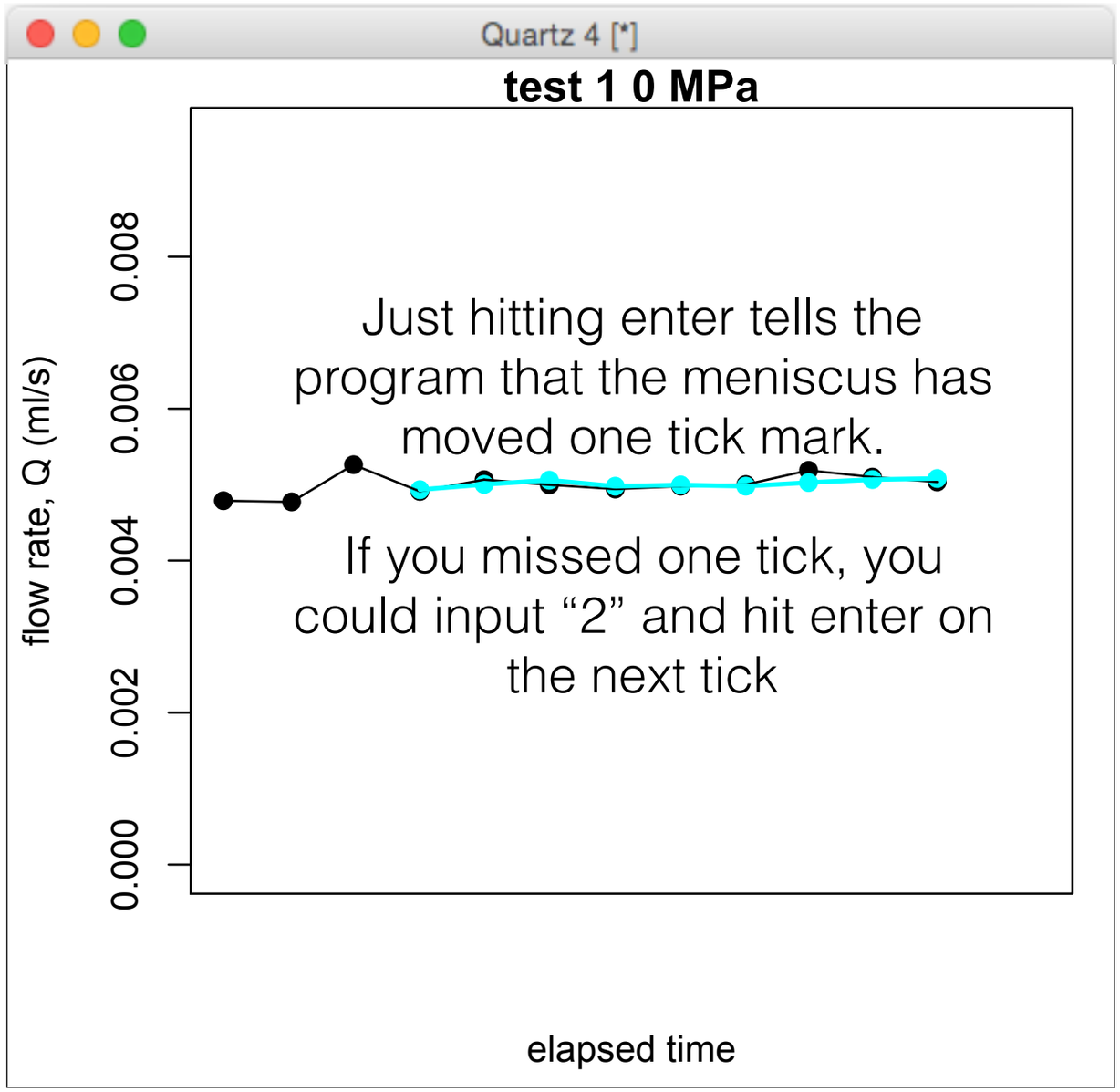
Making measurements with a pipette

R Console

~/Desktop

Help Search

```
>
> cond(1,"test",0,resl=0.01,manul=T)
ready to start! increment = 0.01 ml (press
enter)
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
```



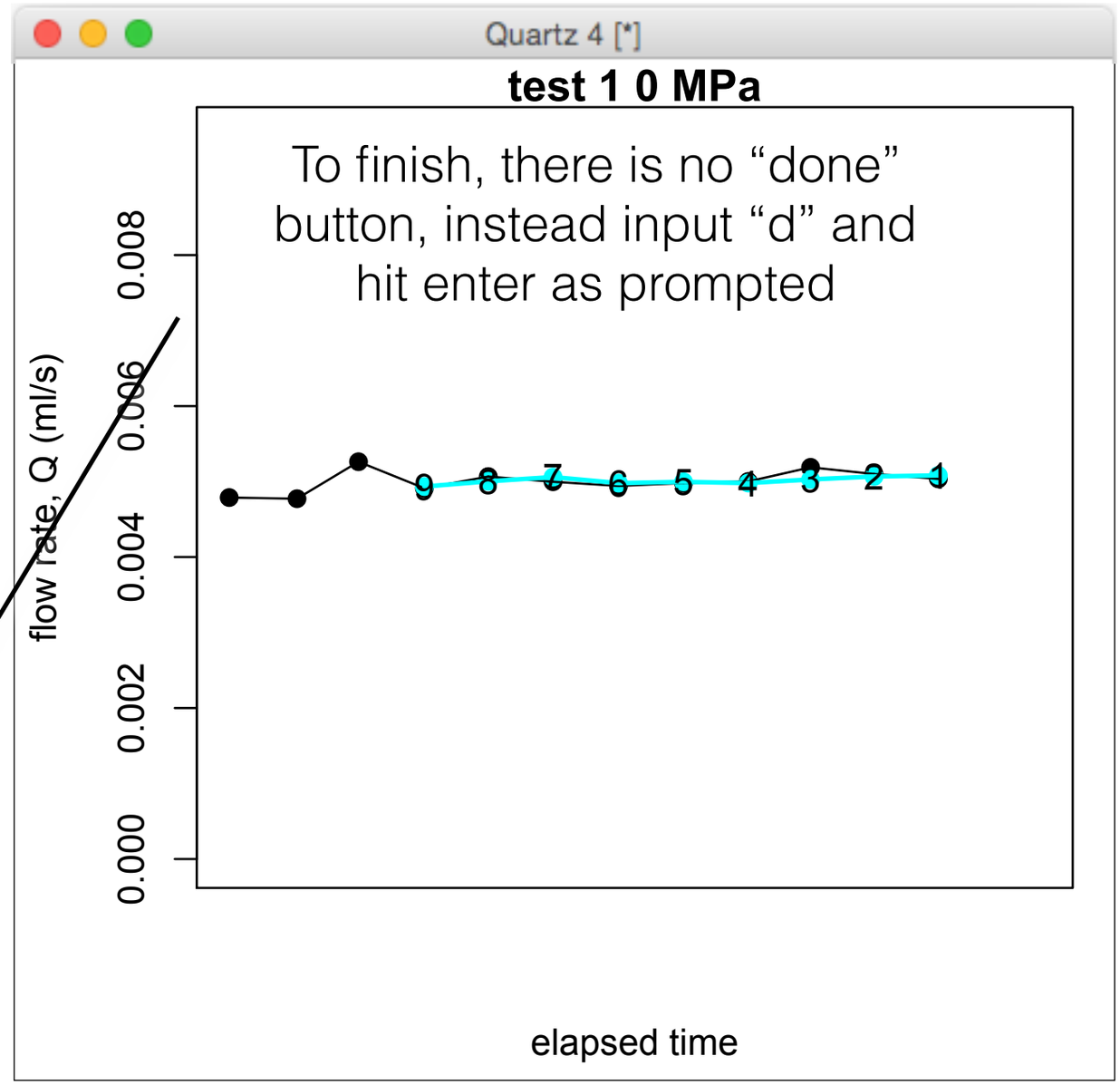
Making measurements with a pipette

R Console

~/Desktop

Help Search

```
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done d
```



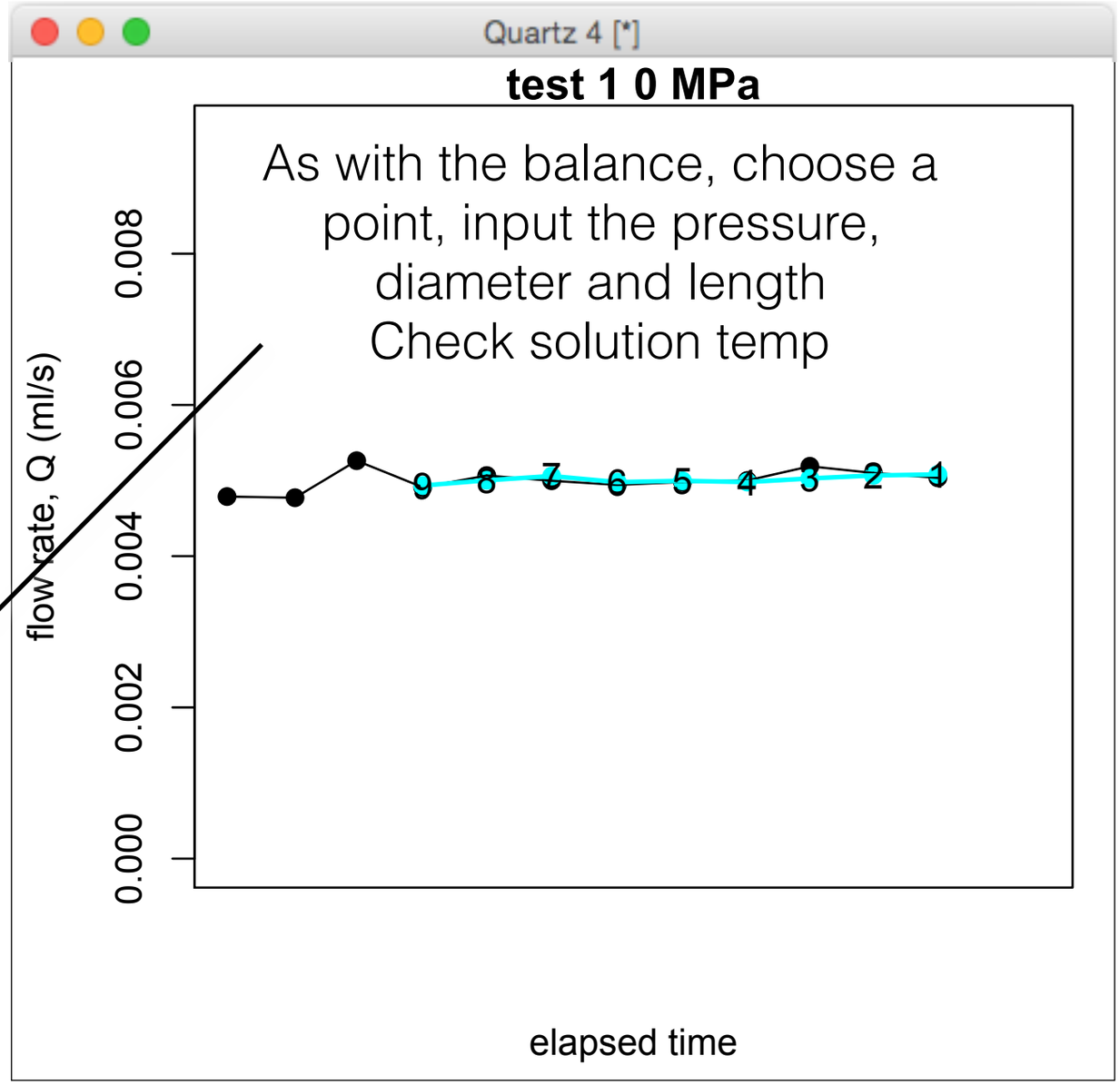
Making measurements with a pipette

R Console

~/Desktop

Help Search

```
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done d
which point to keep? (blank=last)
ending pressure? (cm) 8
d.mm blank and no previous. d.mm= 3.2
l.mm blank and no previous. l.mm= 152
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
```



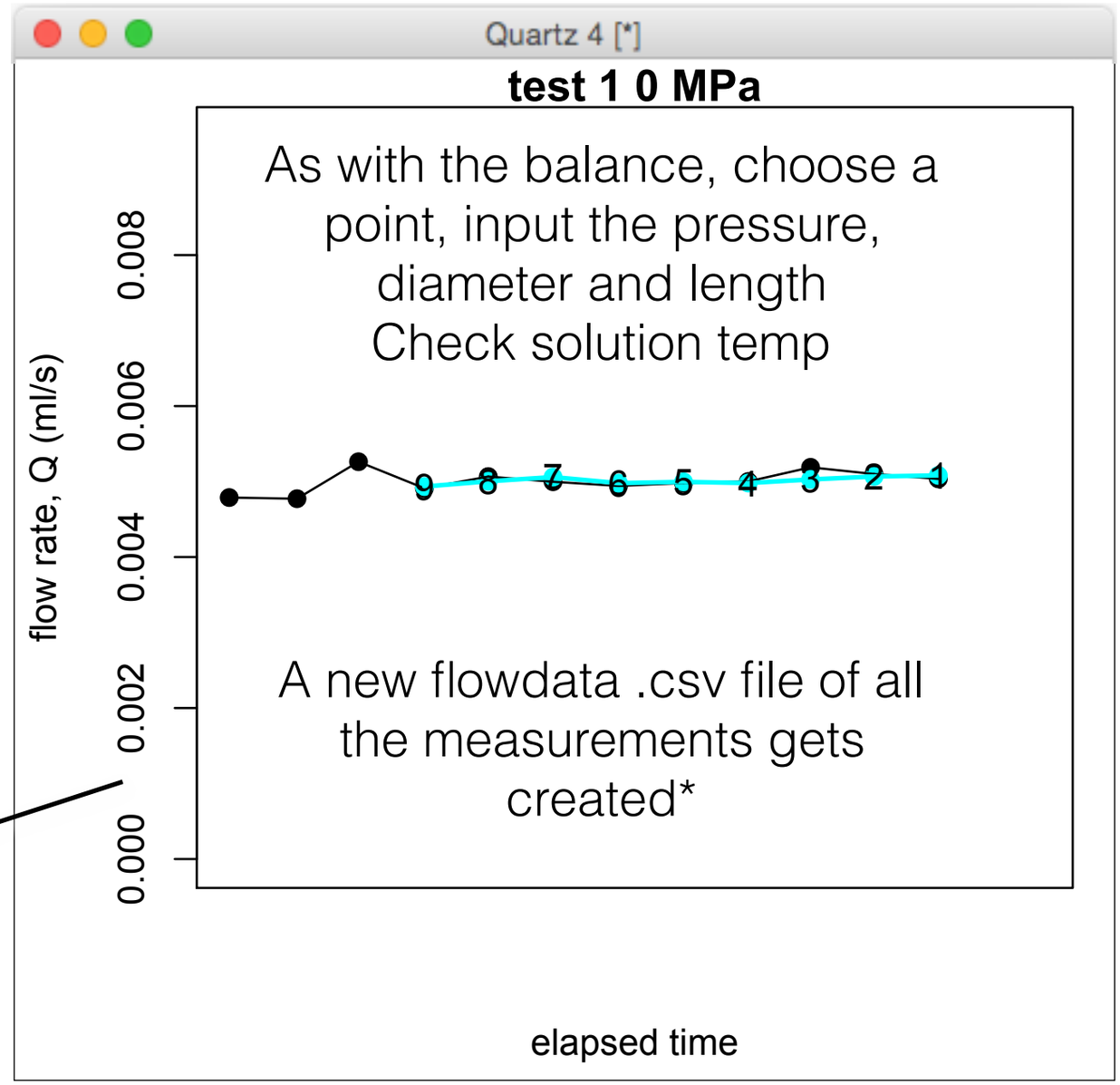
Making measurements with a pipette

R Console

~/Desktop

Help Search

```
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done d
which point to keep? (blank=last)
ending pressure? (cm) 8
l.mm blank and no previous. l.mm= 152
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('1','test',
0,manul=T,fix=T)"
“data written in NEW file as: 2015-12-09
12-24-27 test flowdata manul.csv to /users/
duncan/desktop”
```



*this .csv will have nearly the same layout as one created when using the balance. The key difference is units will be in ml instead of g. Note that ‘manul’ appears in the file name. This prevents an error if you happen to use the balance and pipette on the same species

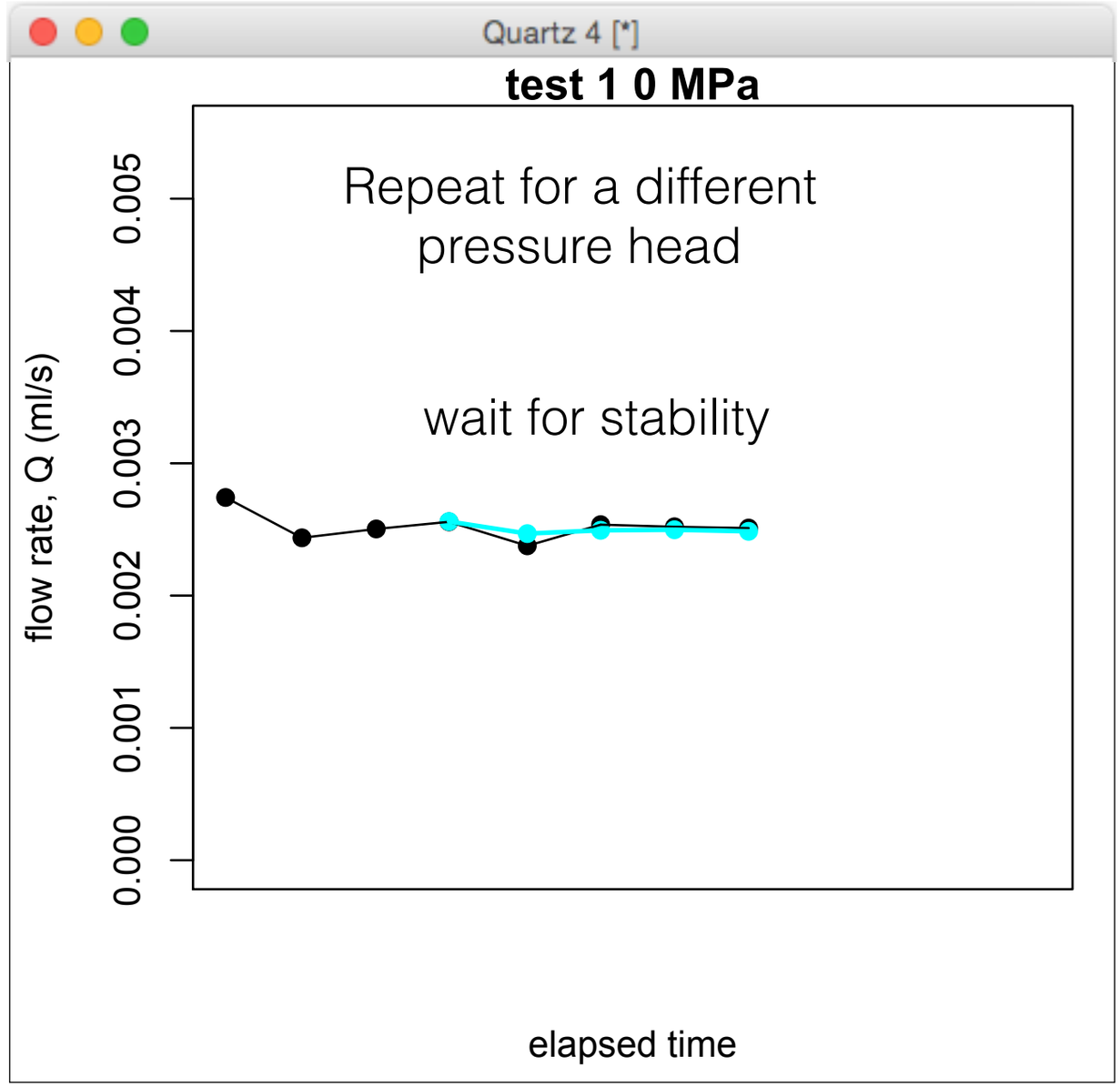
Making measurements with a pipette

R Console

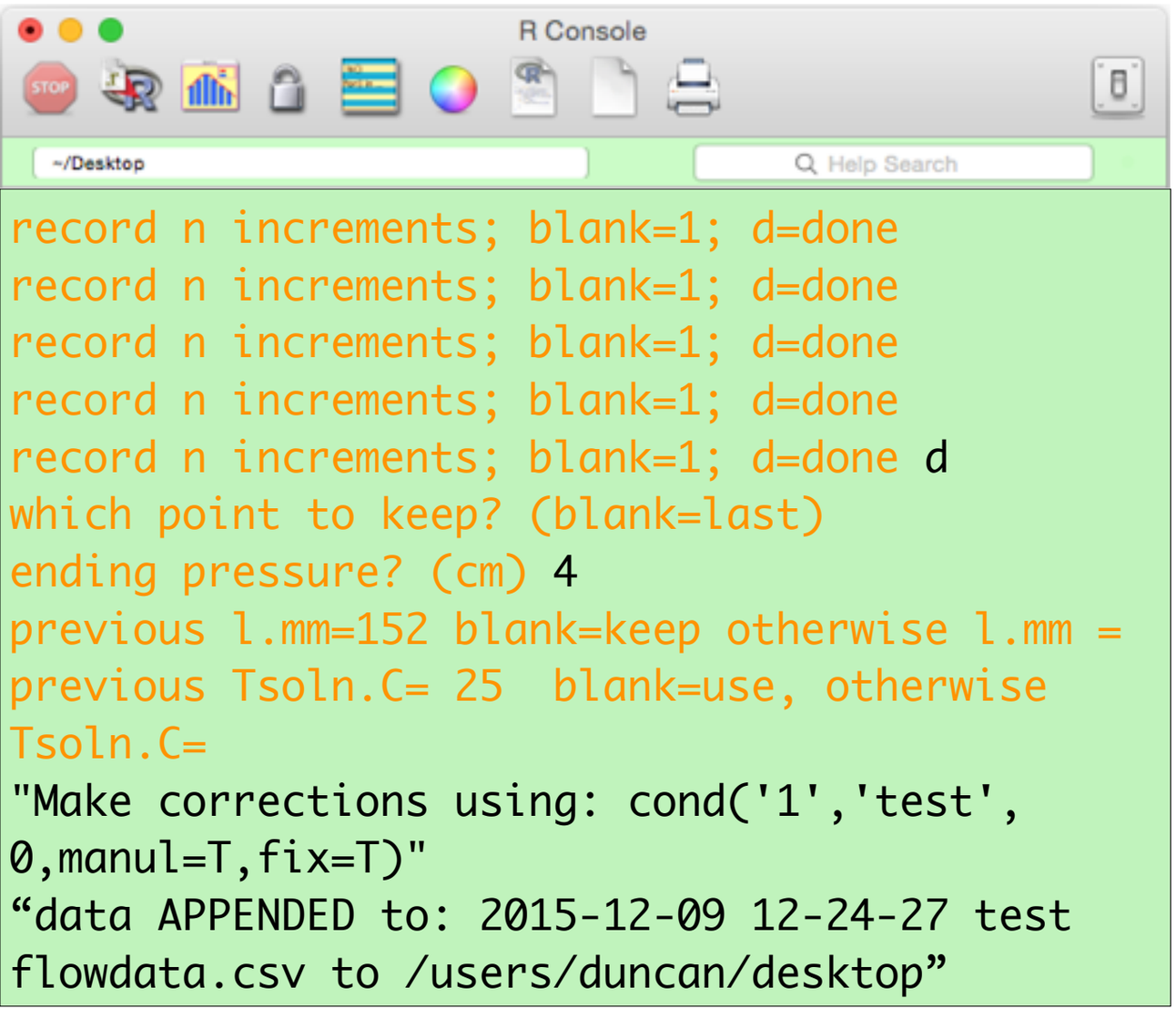
~/Desktop

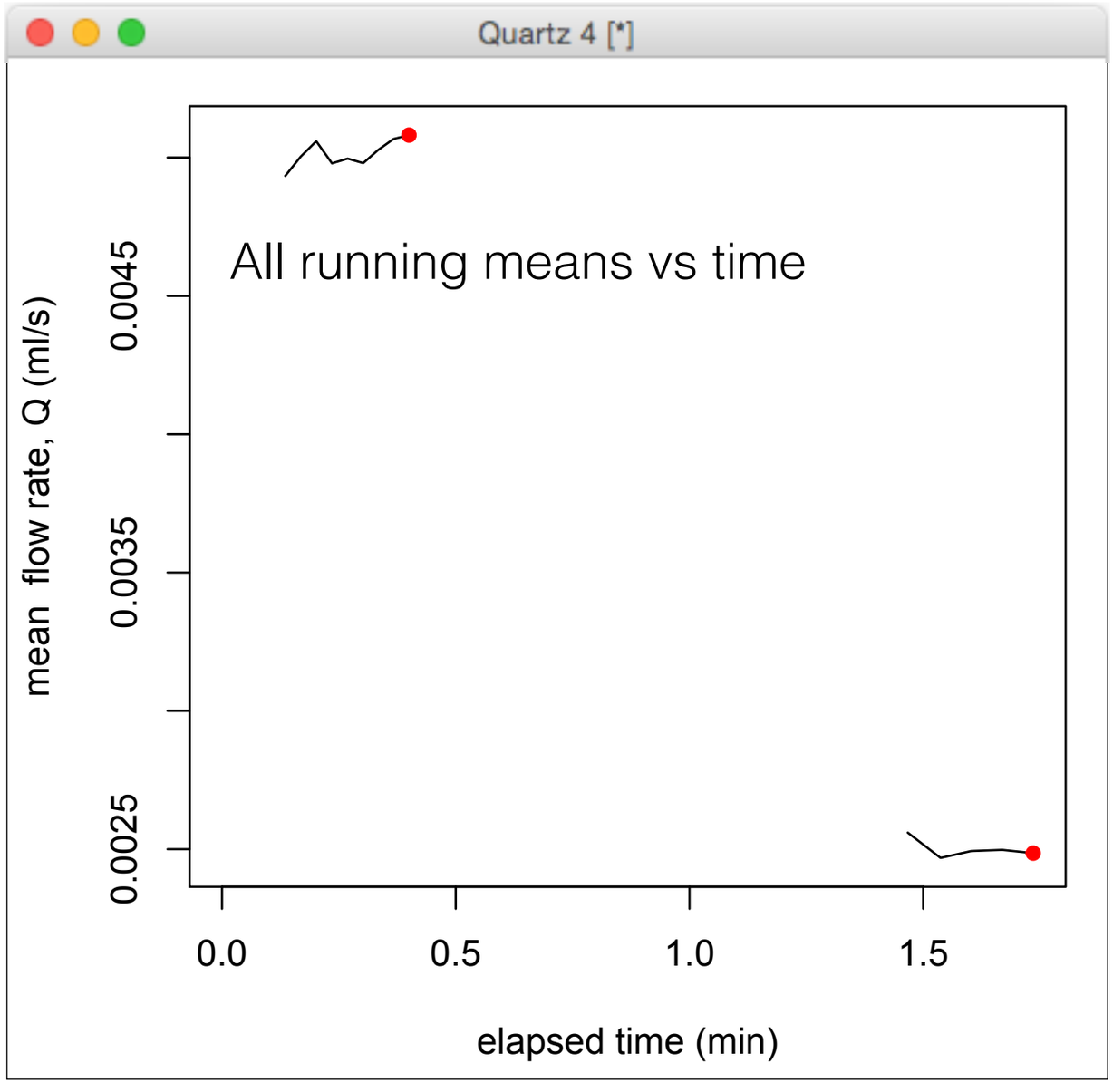
Help Search

```
12-24-27 test flowdata manul.csv to /users/
duncan/desktop”
> cond(1,”test”,0,resl=0.01,manul=T)
ready to start! increment = 0.01 ml (press
enter)
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done d
```



Making measurements with a pipette





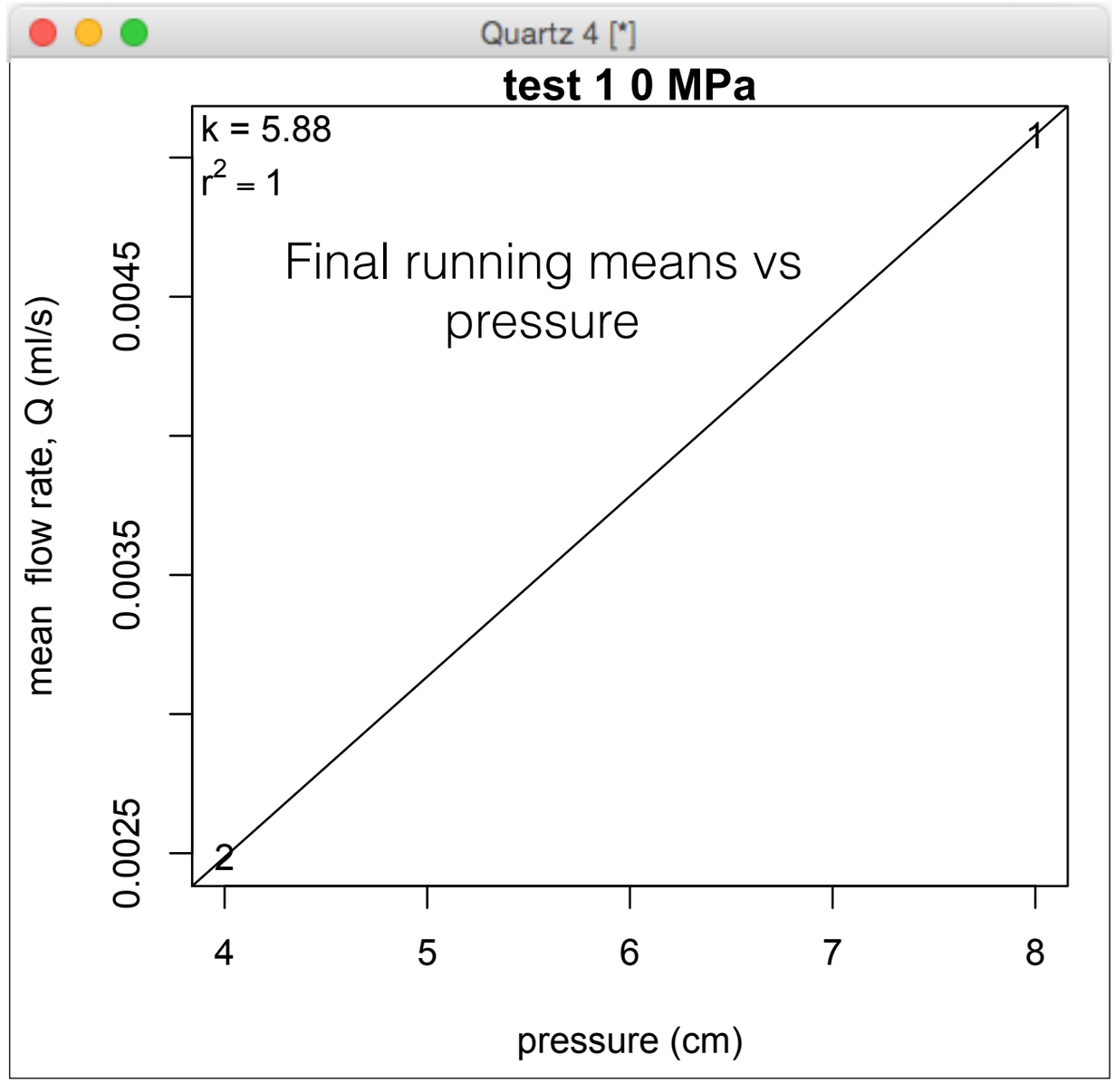
Making measurements with a pipette

R Console

~/Desktop

Help Search

```
record n increments; blank=1; d=done d
which point to keep? (blank=last)
ending pressure? (cm) 4
previous l.mm=152 blank=keep otherwise l.mm =
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('1','test',
0,manul=T,fix=T)"
“data APPENDED to: 2015-12-09 12-24-27 test
flowdata.csv to /users/duncan/desktop”
“(go back one plot to see all mean flow
rates)”
exclude points? (input number to exclude,
blank=no change)
```



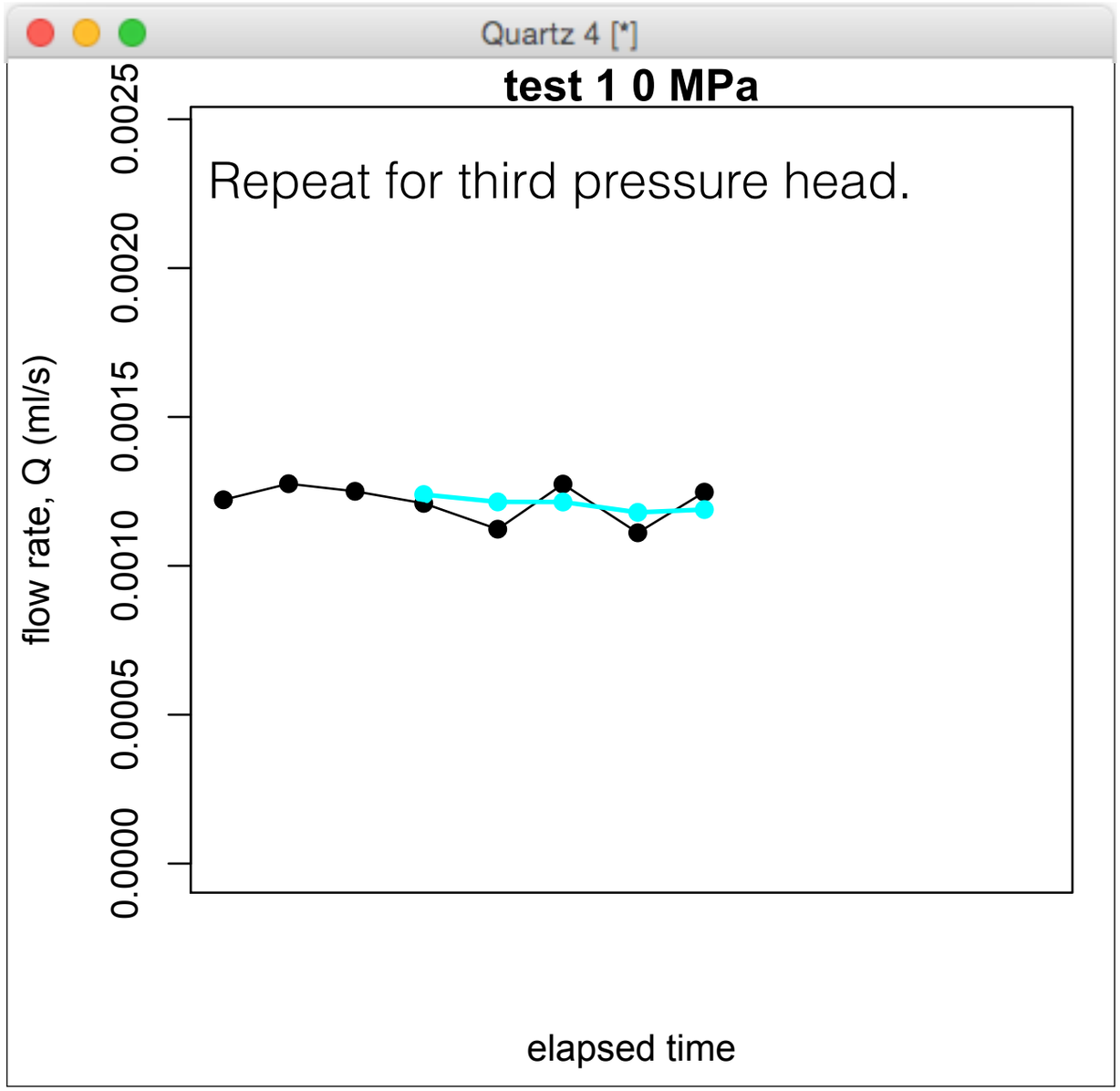
Making measurements with a pipette

R Console

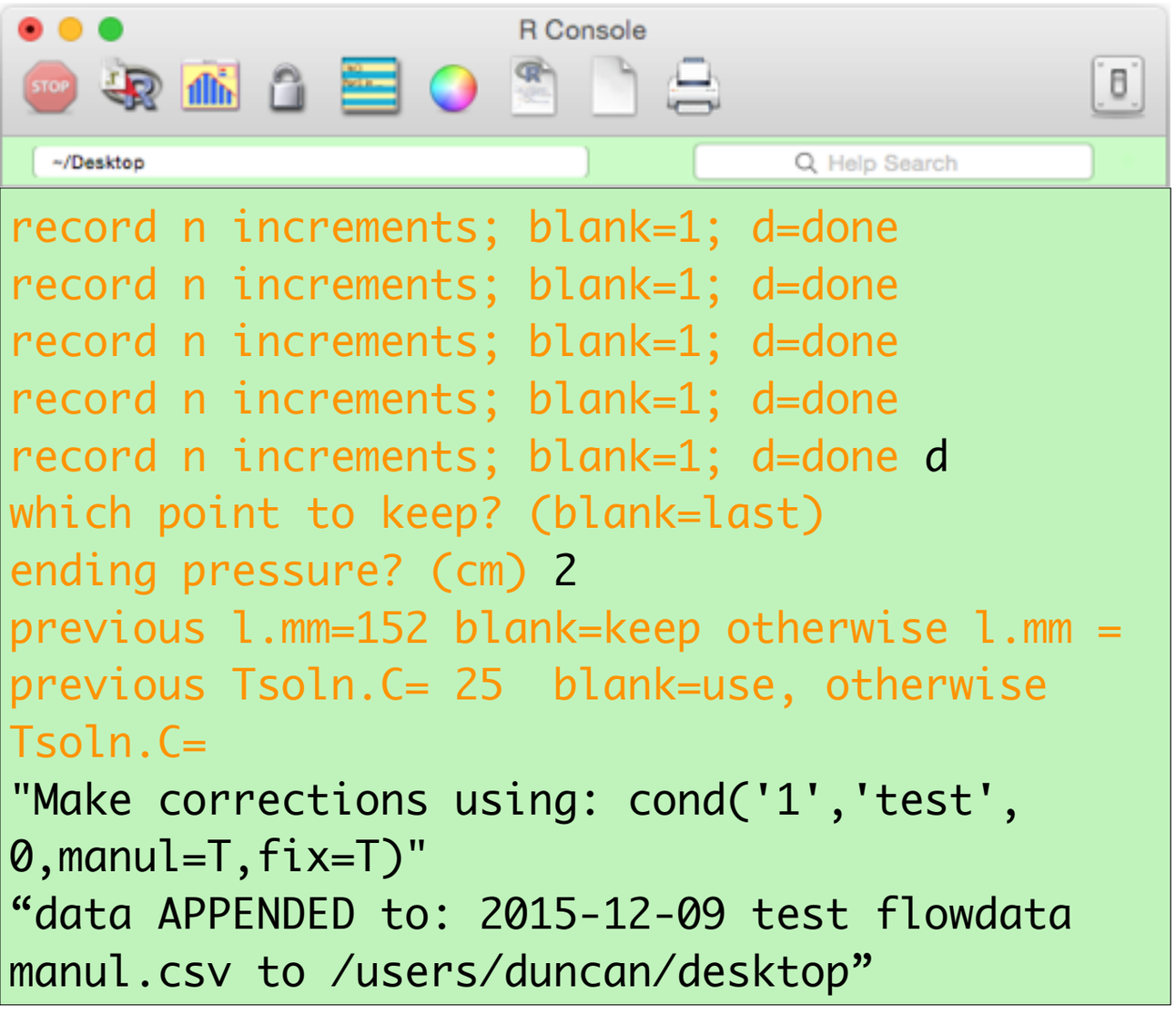
~/Desktop

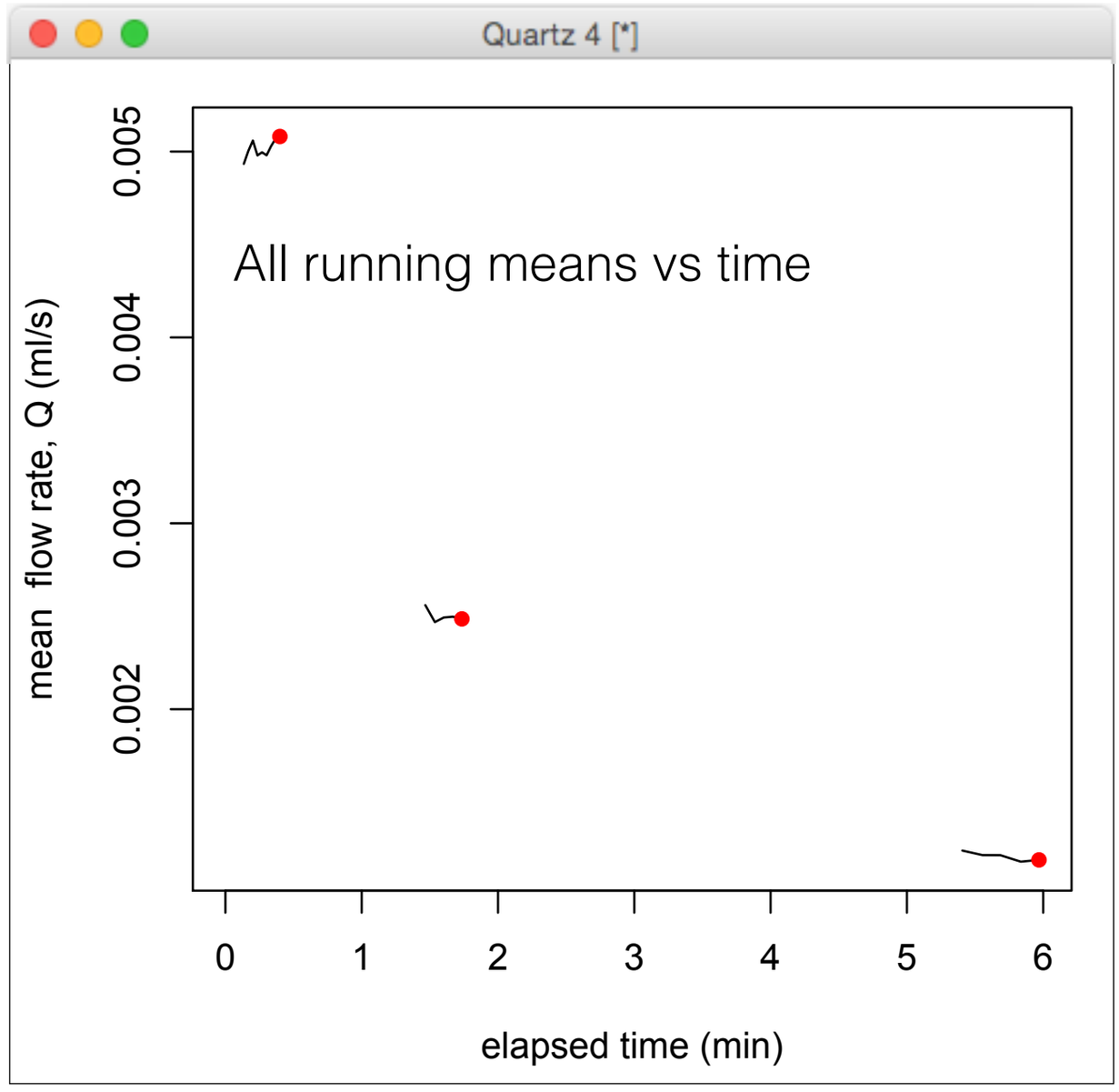
Help Search

```
blank=no change)
> cond(1,"test",0,resl=0.01,manul=T)
ready to start! increment = 0.01 ml (press
enter)
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done
record n increments; blank=1; d=done d
```



Making measurements with a pipette



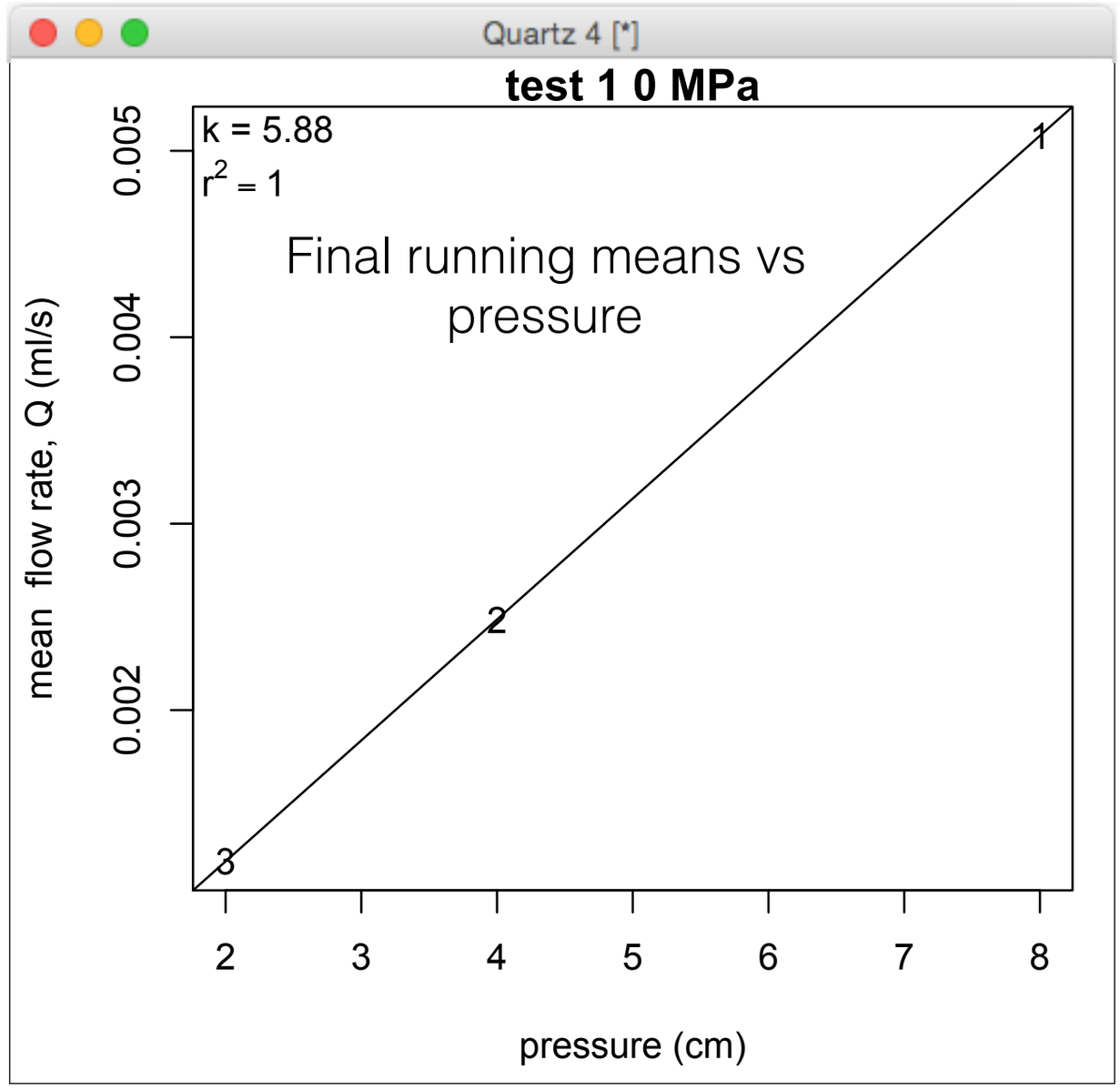


Making measurements with a pipette

R Console

~/Desktop Help Search

```
which point to keep? (blank=last)
ending pressure? (cm) 2
previous d.mm=3.2 blank=keep otherwise d.mm =
previous l.mm=152 blank=keep otherwise l.mm =
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('1','test',
0,manul=T,fix=T)"
“data APPENDED to: 2015-12-09 test flowdata
manul.csv to /users/duncan/desktop”
“(go back one plot to see all mean flow
rates)”
exclude points? (input number to exclude,
blank=no change)
```

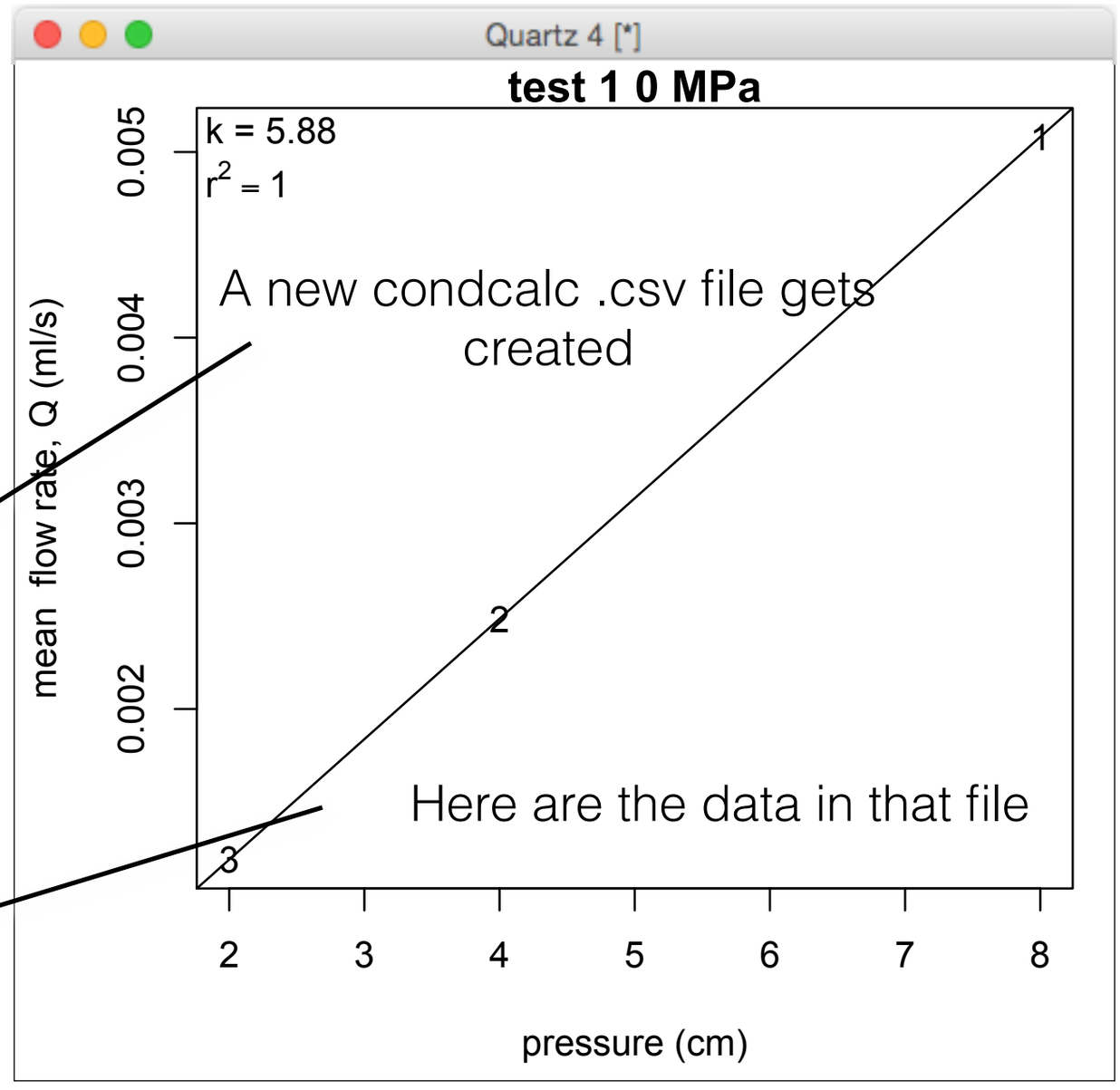


Making measurements with a pipette

R Console

~/Desktop Help Search

```
"data APPENDED to: 2015-12-09 test flowdata
manul.csv to /users/duncan/desktop"
"(go back one plot to see all mean flow
rates)"
exclude points? (input number to exclude,
blank=no change)
save conductance? (y=yes blank=no) y
"data written in NEW file as: 2015-12-09 test
condcalc manul.csv to /users/duncan/desktop"
     t.day   sp numbr  P.MPa          nomID    stemID  l.mm
1  343.235 test      1      0   test 1 0 MPa    test 1   152
    d.mm  k.g.s.MPa         r2  K.g.mm.s.MPa
1    3.2   5.900161  0.9997041      896.8244
Ks.g.s.MPa.mm  plc
1     111.511    0
```



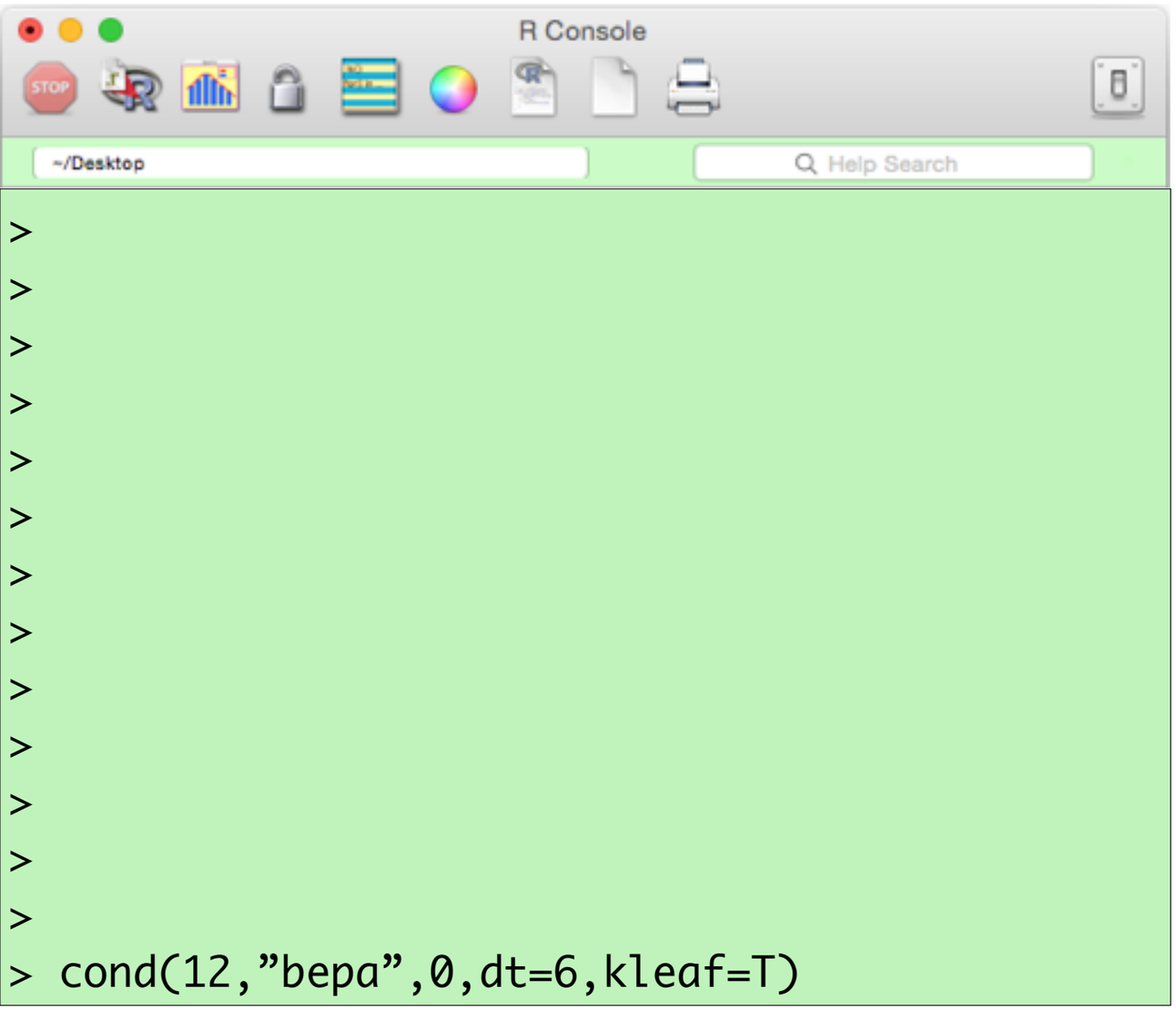
Measuring leaves
(balance or pipette)

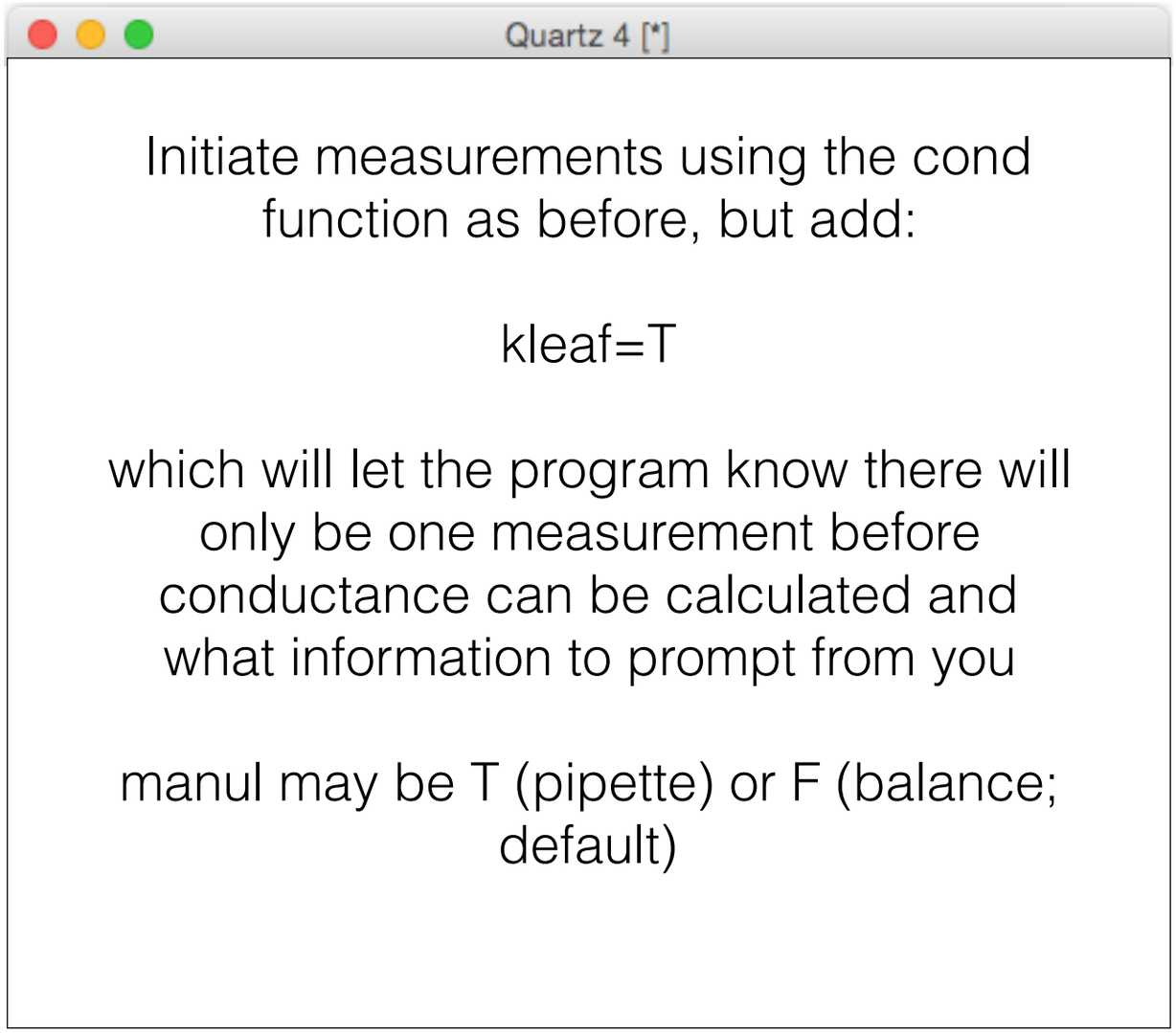
The program may be configured to measure hydraulic conductance of leaves with the evaporative flux method

The protocol of measuring background flow rates doesn't lend itself to leaf hydraulics very well. The flow through a transpiring leaf depends on leaf water potential, which cannot be measured without disrupting hydraulic conductance (e.g. pressure bomb or chamber psychrometry).

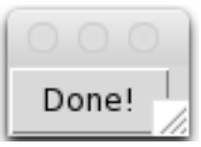
Given this limitation, the program calculates leaf hydraulic conductance from a single flow rate and water potential

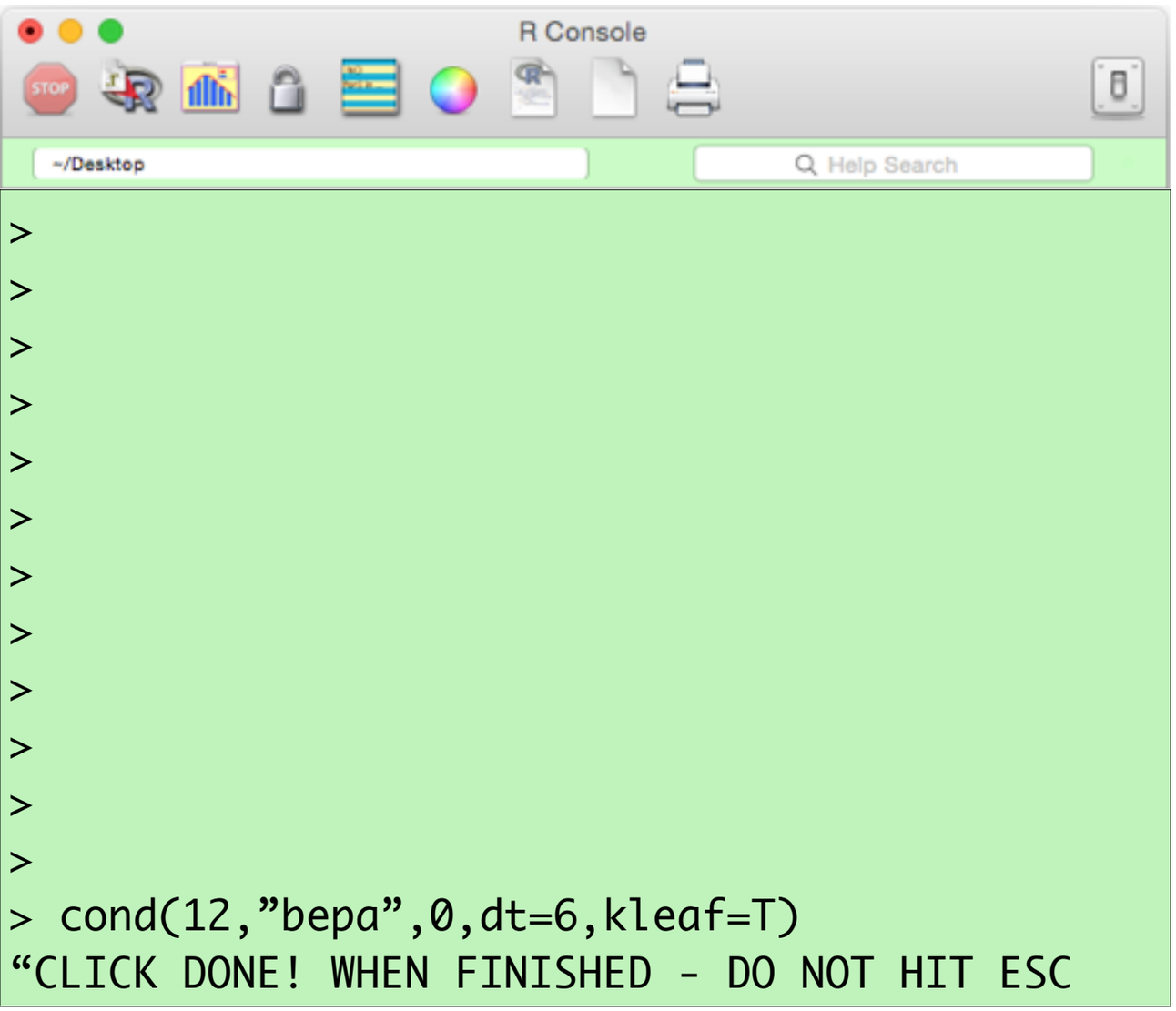
Making leaf measurements (shown with a balance)

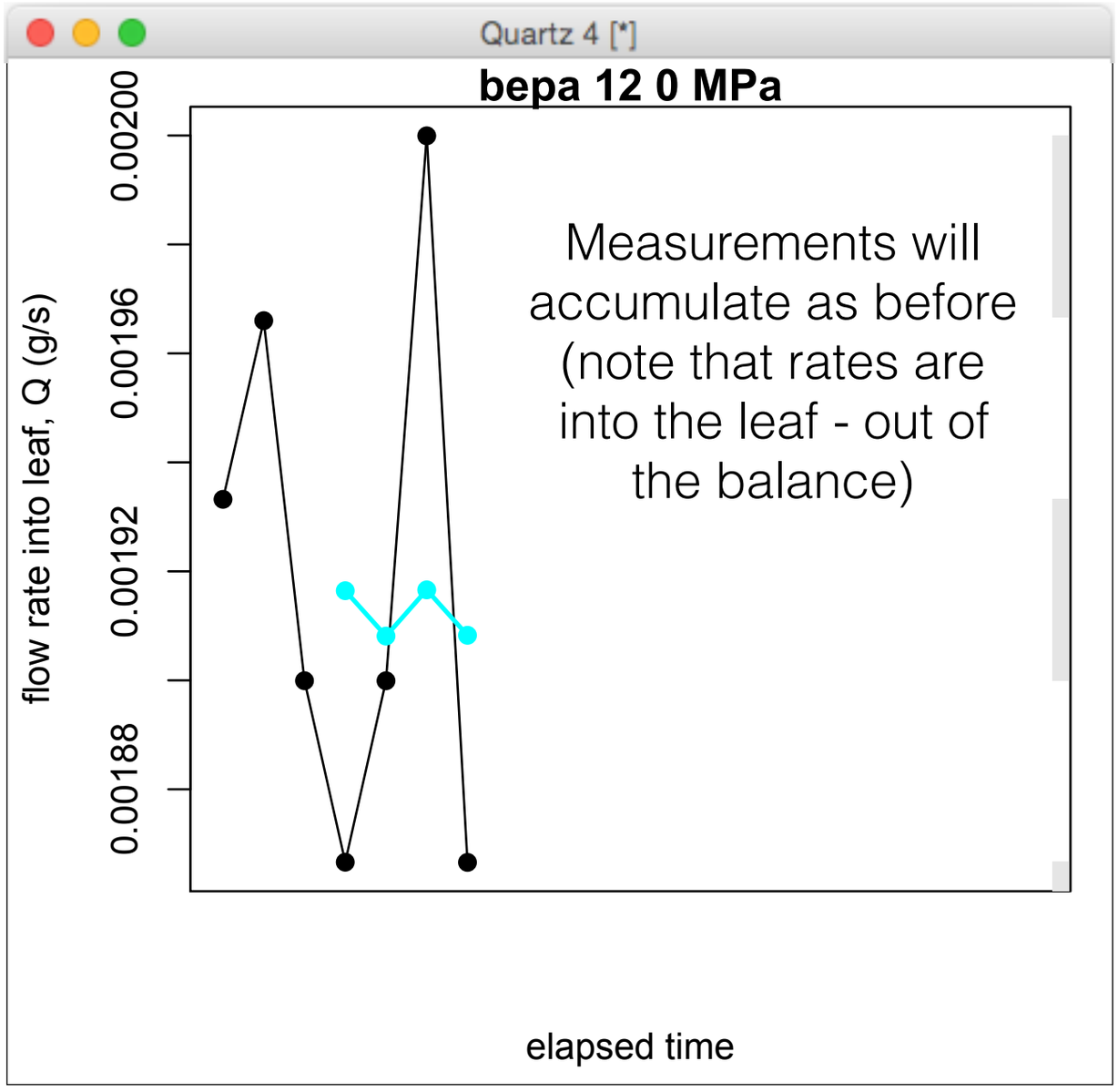




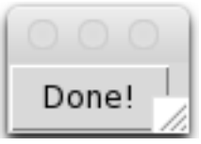
Making leaf measurements (shown with a balance)

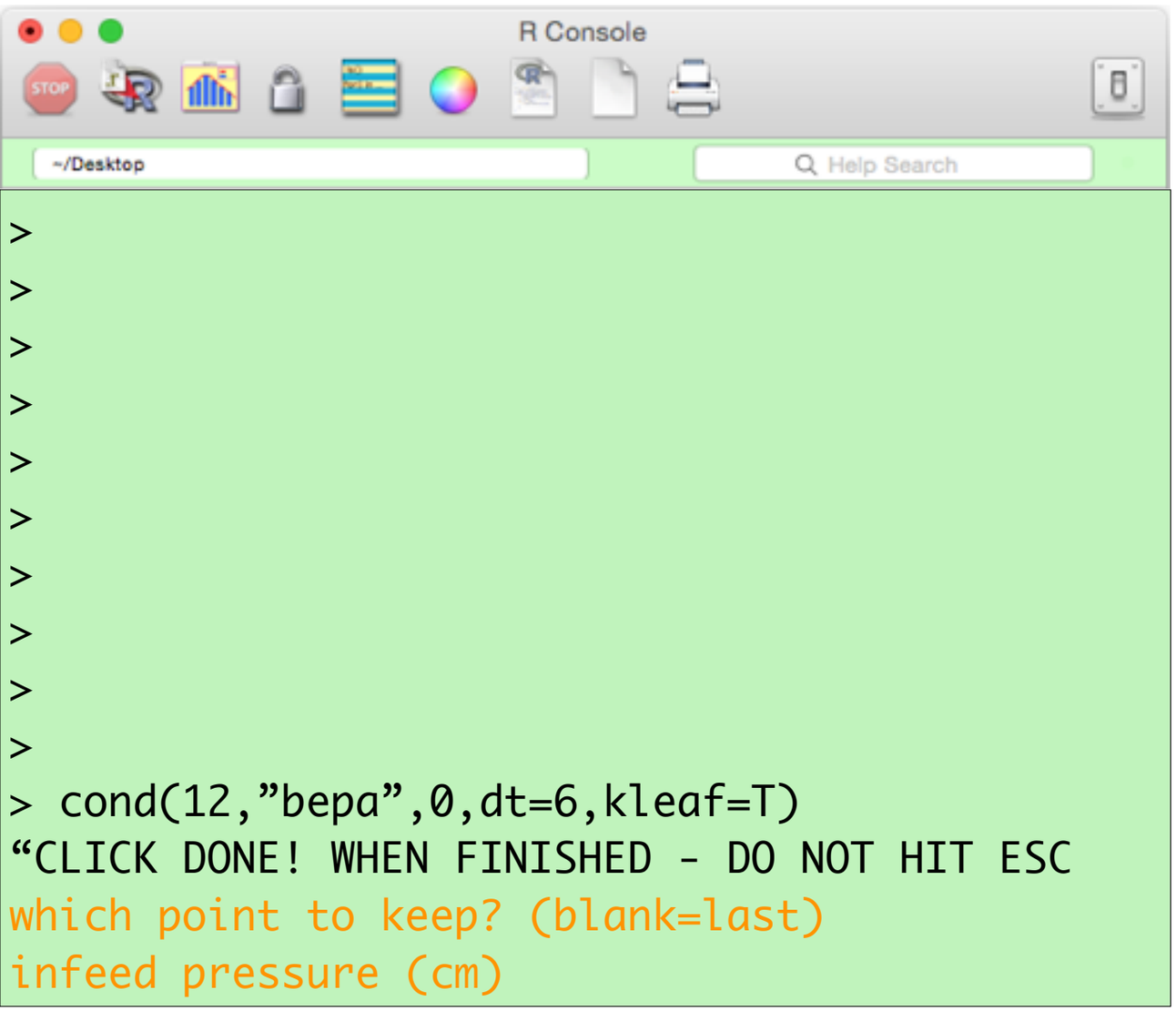


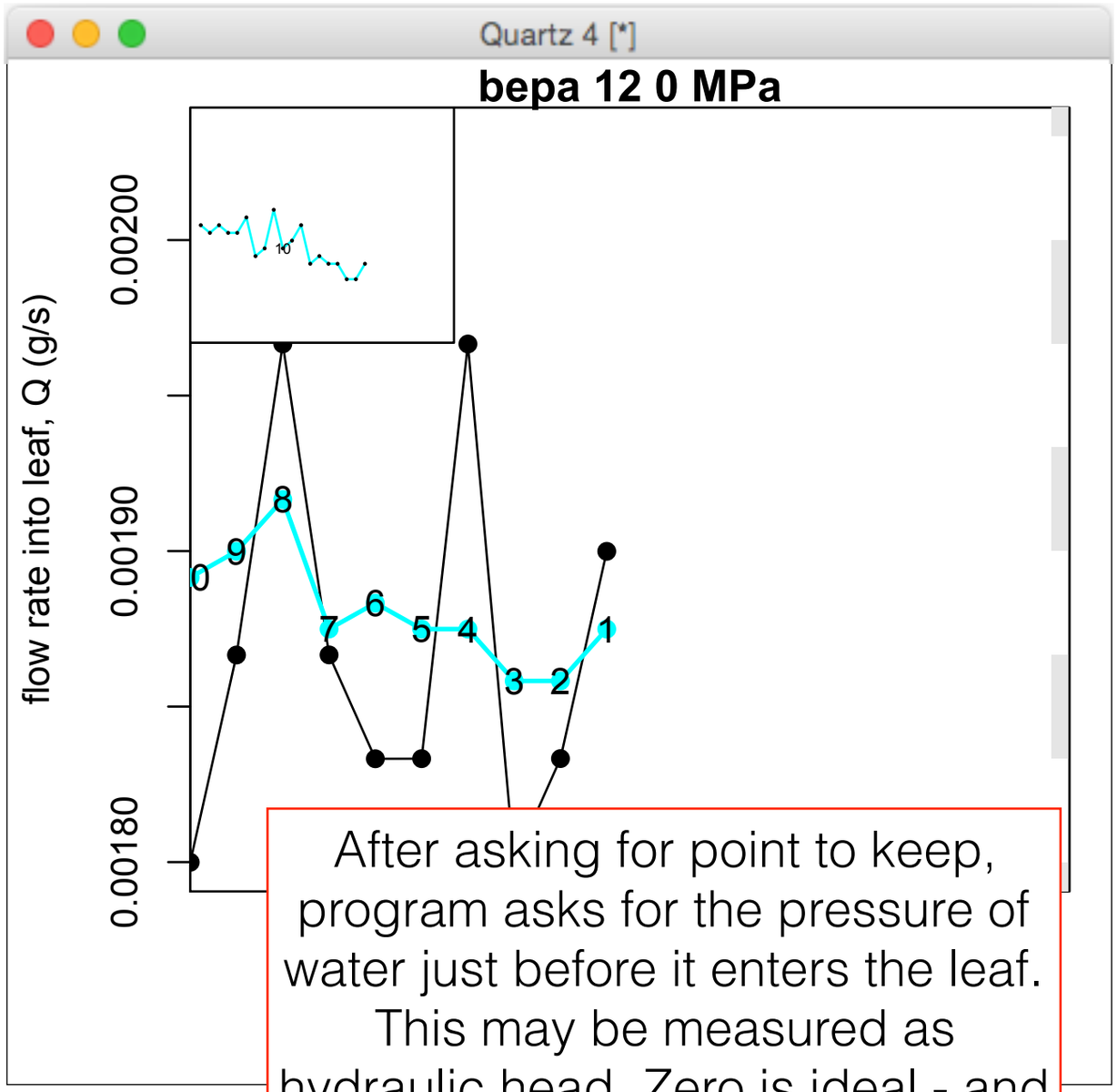




Making leaf measurements (shown with a balance)

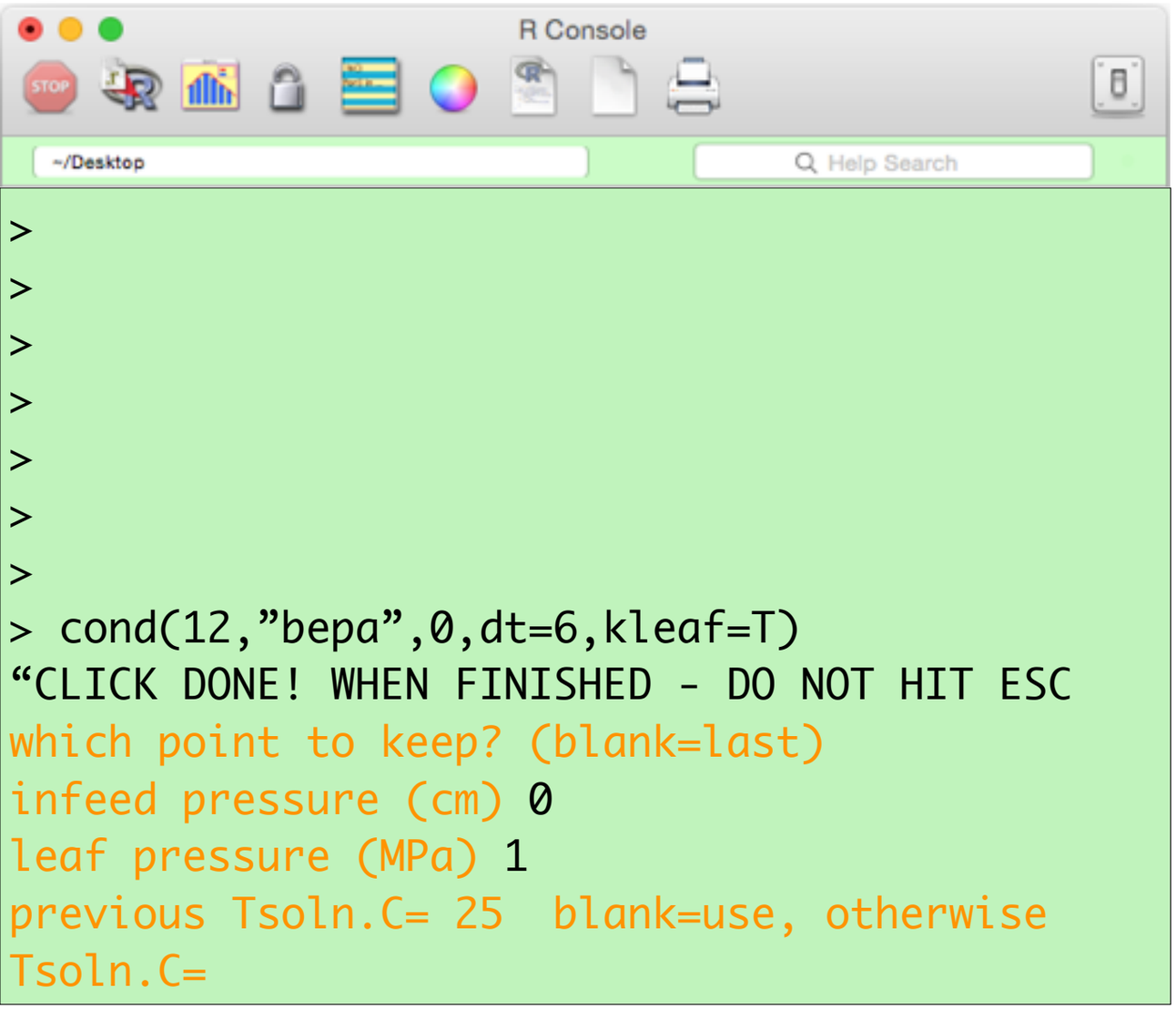


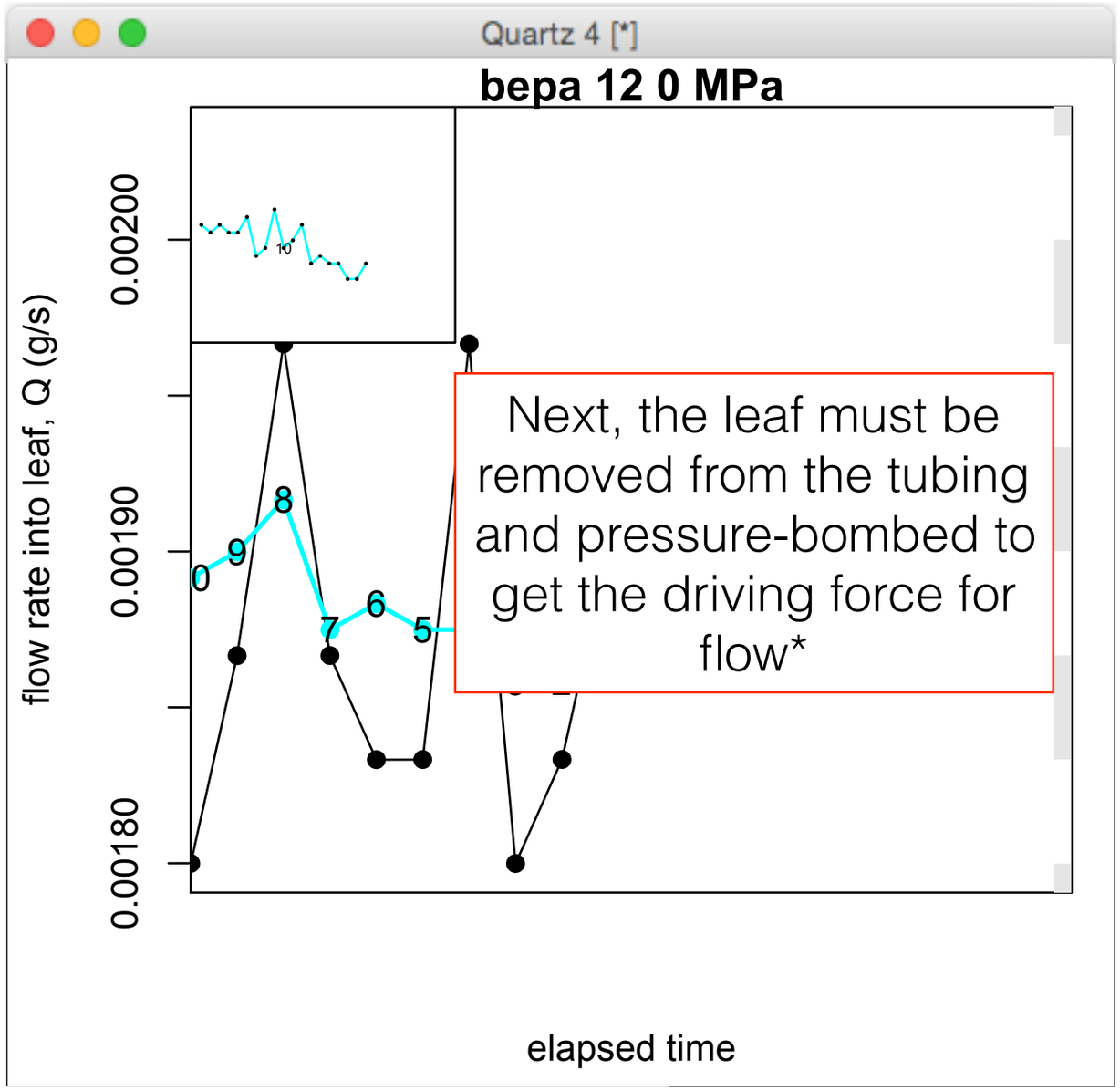




After asking for point to keep, program asks for the pressure of water just before it enters the leaf. This may be measured as hydraulic head. Zero is ideal - and a good assumption if unknown.

Making leaf measurements (shown with a balance)





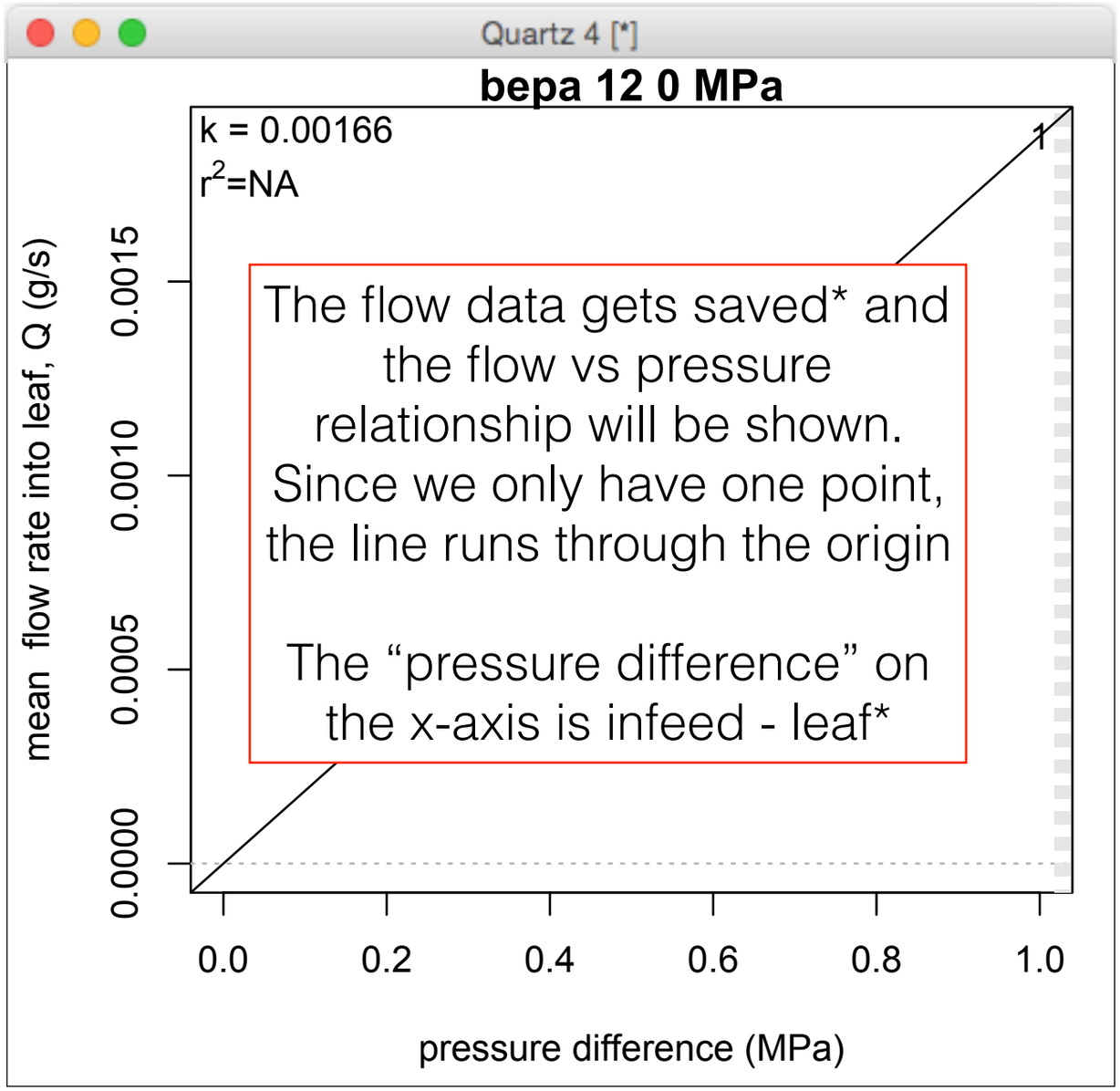
*The assumption is that leaf pressure is a negative number. If your input is positive, the program will make it negative.

Making leaf measurements (shown with a balance)

R Console

~/Desktop Help Search

```
>
>
>
> cond(12,"bepa",0,dt=6,kleaf=T)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
infeed pressure (cm) 0
leaf pressure (MPa) 1
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('12','bepa',
0,kleaf=T,fix=T)"
"data written in NEW file as: 2015-12-09 bepa
flowdata kleaf.csv to /users/duncan/desktop"
```



*this .csv will have a different layout from one created when measuring stems (or roots). Note that 'kleaf' appears in the file name. This prevents an error if you happen to measure leaves and stems or roots on the same species

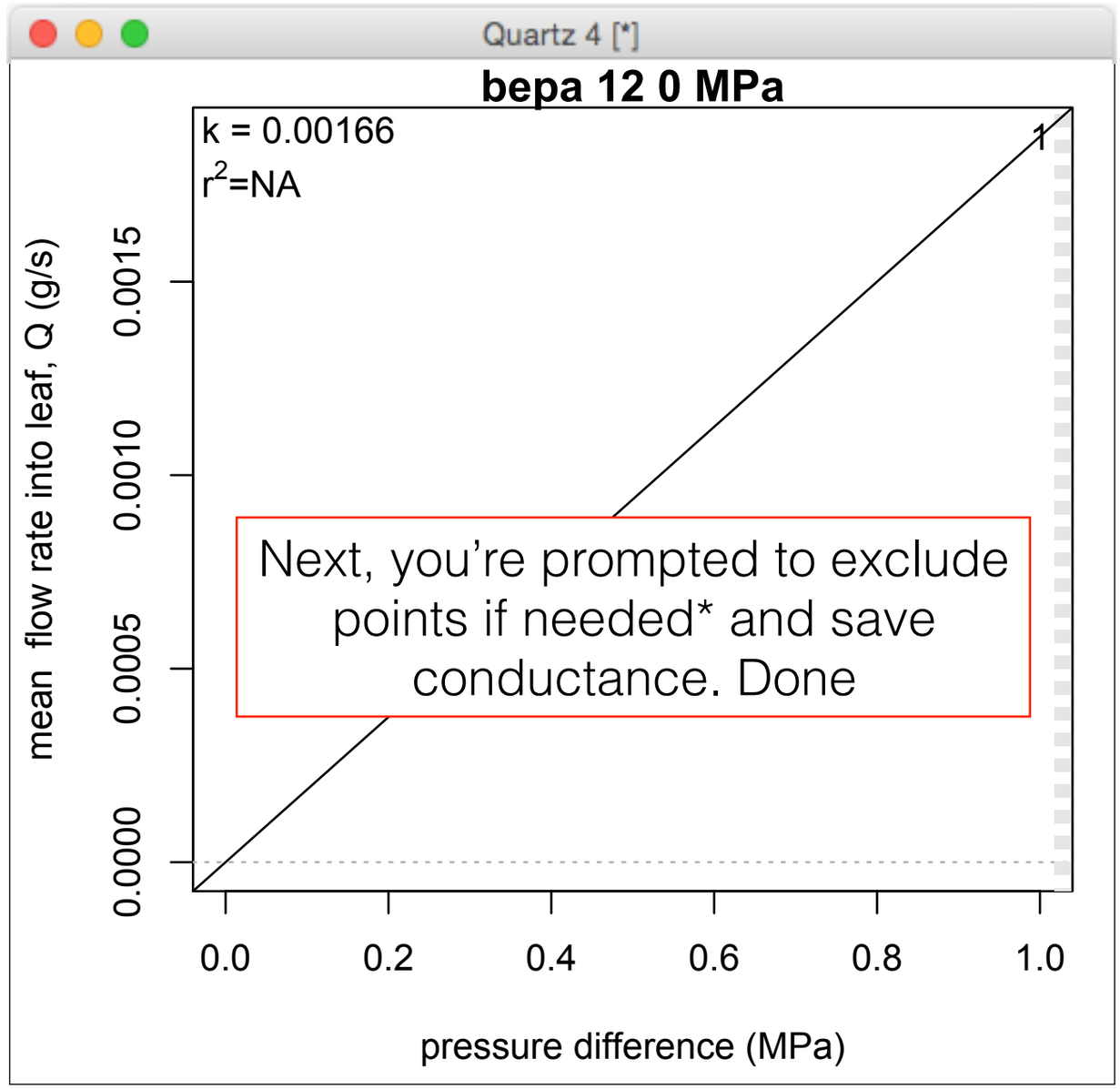
Making leaf measurements (shown with a balance)

R Console

~/Desktop

Help Search

```
> cond(12,"bepa",0,dt=6,kleaf=T)
"CLICK DONE! WHEN FINISHED - DO NOT HIT ESC
which point to keep? (blank=last)
infeed pressure (cm) 0
leaf pressure (MPa) 1
previous Tsoln.C= 25  blank=use, otherwise
Tsoln.C=
"Make corrections using: cond('12','bepa',
0,kleaf=T,fix=T)"
"data APPENDED to: 2015-12-09 bepa flowdata
kleaf.csv to /users/duncan/desktop"
exclude points? (input number to exclude,
blank=no change)
save conductance? (y=yes blank=no) y
```



*admittedly, removing points may not make sense as you can't create a point unless you measure xylem pressure and therefore prevent further hydraulic measurement

Appendix A: Functions and their parameters

Parameters of the cond function (and their defaults)

```
cond(
      numbr,              # stem number (or letter, use quotes with letters)
      sp,                 # species (must be in quotes)
      Ptreat.MPa=0,       # treatment pressure in MPa [must be a number; can be
                           c(rpm,rmax.mm) if using a centrifuge - see pcent() function]
      runmean=4,          # number of values in running mean
      dt=6,               # target time (s) between balance readings
      resl=0.0001,        # resolution of balance (g) or pipette (ml)
      mxplot=10,          # leave space for this many measurements when making a new
                           plot after existing one is full
      manul=F,            # manual mode (T for use with pipette)
      testmode=F,         # create random numbers instead of reading the balance
                           (useful for demonstration or when altering code)
      ovrl=0.3,           # size of inset showing overall running mean flow data - as
                           a fraction of plot size (0=no inset)
      kleaf=F,            # is measurement on a leaf? If T, will ask for leaf pressure
                           and not diam or length. Also nmin=1
      nmin=3,             # the minimum number of points required to calculate k from
                           Q vs P
      fix=F)              # option to skip measurements and change an input in a
                           previous measurement and/or calculate conductance
```

Appendix A: Functions and their parameters

Parameters of the showvuln function (and their defaults)

```
showvuln=(
     sp,                              # species
     yax=c("k.","K.","Ks")[3],        # what to plot on y axis (conductance,
                                       conductivity or specific conductivity (default),
                                       respectively)
     as.plc=F,                        # option to plot percent loss conductivity, if T,
                                       yax is ignored
     horiz=90,                        # add a horizontal line at this height in PLC
                                       plot (e.g. use 90 PLC as a cutoff and see how
                                       close you are)
     retrn=F)                         # option to return entire condcalc.csv file
```

Note: this function will search the working directory for .csv files that contain "*sp* condcalc". If there are multiple matches, it will ask which one to use.

Miscellaneous functions and their parameters

```
pcent(          # returns pressure induced by centrifuge in MPa
     rpm,         # RPM of centrifuge
     rmax.mm,     # radius from center of rotation to meniscus in rotor cup
     r=0)         # point of interest in stem relative to center of rotation
                  Note: function uses density of water = 998.2 kg m-3 (20 C)


rpmcent(        # returns RPMs needed to induce given pressure
     p,           # desired pressure in MPa (needs to be negative)
     rmax.mm      # radius from center of rotation to meniscus in rotor cup
     r=0)         # point of interest in stem relative to center of rotation
                  Note: function uses density of water = 998.2 kg m-3 (20 C)


phead(          # converts pressure head in cm to MPa
     p.cm,        # head in cm
     rho,         # density of water in kg m-3
     grav)        # gravity in m s-2
```

Internal functions

`cond()` uses functions `corner()` and `resbar()` to respectively add text and resolution bars to plots

Times are represented in R as “seconds since 1970”. `julr()` helps convert this to the more useful decimal day.

Balance outputs are interpreted by `decod()`, which has options for Sartorius, Metler-Toldeo, Ohaus and Scientech balances. More details in Appendix B.

`frbind()` forces `rbind()` to work even when column names/numbers do not match. This prevents erroring out if you have added/removed columns or changed their names. While it prevents an error, it will not rectify changed names with the names it expects. The code just creates the new columns that it expects.

Appendix B: The decod() function

The internal function decod() parses the balance output into a useable number. For example, a Sartorius of Scientech balance might print

“+” “62.4317” “g”

or

“62.4317” “g”

To parse this, the program needs to know it will print multiple components and the first component is either a sign or a number. The decod() is programmed to look at the first component and decide if it’s a sign. If it’s a sign, then the second component must be a number so we’ll take that sign and apply it to the number. In the code, which component is the number is called `wch` (i.e. `wch=1 or wch=2`, here). On a Sartorius balance, by default, the above printout may be preceded by “N” which throws off the above logic. To remedy this, change the balance settings e.g. Menu>SETUP>PRNT.OUT>PRT.INIT>OFF

A Mettler balance is somewhat simpler in that it might print:

“S” “D” “62.4317” “g”

where the number is always the third component (i.e. `wch=3`), which will include the negative sign if needed. For an Ohaus balance, `wch=16.`

If communication is working but you have a different balance or you’re having parsing issues, there is a commented line (~ line 106) that says `#print(as.character(tst))`. I suggest uncommenting this and running the program for a bit with stable vs unstable and positive vs negative weights to see what the general format is and which component is the number. Then change decod() [if you’re comfortable doing so] or ask me for help.

Appendix C: Dealing with input errors

A number of features prevent the user from inputting values that cause the program to error. For example, when asked which point to keep, the input can only be an integer between 1 and the total number of mean flow rates, which often helps if you accidentally enter pressure instead (often not an integer). Pressure, diameter, length and temperature must be numbers. The program will ask for new values if these criteria are not met.

Some accidents are accepted by the program though. If you realize you just entered the wrong value, **proceed through the remaining prompts.** Most common errors are fixed by subsequently running cond(…,fix=T). After finishing the measurement, the program gives you the exact code you need to run. Using fix=T will prompt you for which measurement to fix (i.e. the numbers shown in the Q vs P plot), what to fix (options depend on measurement type - leaf or stem/root), and what the corrected value is. Changes are made to the flowdata csv file then the program proceeds as if a measurement was just completed, allowing you to calculate conductance if needed. If you already calculated conductance with an error, you can manually delete the bad calculation after adding the new calculation.

Appendix D: Known issues / cautions

After measurement, warning(s) stating NAs introduced by coercion are sometimes given. These may be due to bad balance outputs or bad inputs for pressure, diameter or length. This is not known to affect measurements but the warning may cause concern.

Prior to version 14, density of water was always assumed to be 25 C for calculating hydraulic head. User-inputted temperature was only used to calculate viscosity to correct conductivity to 20 C.

You will lose data if you:

- Press ESC instead of clicking Done!
- Press ESC instead following the prompts (actually useful to cancel a measurement)
- Have the flowdata.csv or condcalc.csv file open in another program (e.g. Excel) when ending a measurement (may only matter in Windows)

You will confuse things (and possibly lose data) if you:

- Rename flowdata.csv or condcalc.csv files
- Rename or delete columns in flowdata.csv or condcalc.csv

Appendix E: Anticipated questions:

How do I save my data?

Data are automatically saved to your working directory after every measurement. You need not save anything in R except the conductR code if you alter it

How do I change the defaults in cond()?

In the conductR code where it says cond=function(…) [~line 41] you'll see all the function arguments and their defaults. Change as desired, save and re-source the code into the R console.

What if I input the wrong ____?

Your options are to either 1) start over (good when you just started a measurement and, say, used the wrong ID) 2) use cond(…,fix=T) and follow the prompts or 3) manually edit the saved data file(s). If you calculated conductance with a wrong input, you can recalculate by following the prompts of cond(…,fix=T). But you will need to manually delete the wrong values from condcalc.csv

Why is this not an R package?

It seemed simpler this way to keep everything organized in one file. Plus, this way the user has full access to and control over the code, which allows things like default arguments to be changed. However, there is potential for problems if your variable names overlap with mine. Besides the functions (see Appendix A) and .Tcl variables (i.e. port settings), I use: kwd, elev, lat, btyp

Appendix F: Observations for various balances

With a new Mettler-Toledo balance, I had success changing balance settings to enable Host (instead of Printer), use 9600 baud, 8 bits, no parity, 1 stopbit, handshake Xon/Xoff, end of line <CR><LF>, Ansi/Win character set, continuous mode Off. However, in conductR I used default port settings (including 7 bits, odd parity).

With an old Mettler-Toledo balance, I had success when balance settings matched the default conductR settings (as expected). But this balance would only communicate with a Windows computer.

With a GeneMate balance, port settings were not alterable and were baud 9600, 7 data bits, space parity,1 stopbit, handshake none or xon/xoff. But default conductR port settings (including odd parity) worked fine, as did the Sartorius print command (Esc-P-CR-LF).

My ability to test different balances is very limited. Please pass along info that might help others.