

Body size trends in Neogene tortoises

30.05.2017

Test paleoTS with Fossil Checklist data (but is probably of no use, because they report average body sizes (means, median, something else? what are the respective sample size? maybe ask the authors!?), so this is just for playing around).

Raw data:

```
library(paleoTS)
#setwd("//naturkundemuseum-berlin.de/MuseumDFSRoot/Benutzer/Julia.Joos/Eigene Dateien/MA")
test<-read.csv("test26.5.csv", sep=";", header=TRUE)
test
```

##		Taxon	Age_min	Age_max	Age_mean
## 1		Gopherus pertenuis	0.7810	1.8060	1.29350
## 2		Hesperotestudo johnstoni	0.7810	1.8060	1.29350
## 3		Hesperotestudo oelrichi	0.7810	1.8060	1.29350
## 4		Hesperotestudo turgida	0.7810	1.8060	1.29350
## 5		Megalochelys margae	0.7810	1.8060	1.29350
## 6		Megalochelys sondaari	0.7810	1.8060	1.29350
## 7		Megalochelys sp. [Flores]	0.7810	1.8060	1.29350
## 8		Megalochelys sp. [Java]	0.7810	1.8060	1.29350
## 9		Psammobates antiquorum	0.7810	1.8060	1.29350
## 10		Testudinidae sp. [China]	0.7810	1.8060	1.29350
## 11		Testudo changshanesis	0.7810	1.8060	1.29350
## 12		Hesperotestudo sp. [El Salvador]	0.7810	1.8060	1.29350
## 13		Aldabrachelys abrupta	0.0000	0.0117	0.00585
## 14		Aldabrachelys grandidieri	0.0000	0.0117	0.00585
## 15		Chelonoidis alburyorum	0.0000	0.0117	0.00585
## 16		Chelonoidis sp. [Caicos]	0.0000	0.0117	0.00585
## 17		Chelonoidis sp. [Turks]	0.0000	0.0117	0.00585
## 18		Titanochelon schafferi	5.3320	7.2460	6.28900
## 19		Chelonoidis elata	1.8060	7.2460	4.52600
## 20		Homopus fenestratus	3.6000	1.8060	2.70300
## 21		Chelonoidis lutzae	0.0117	0.1260	0.06885
## 22		Chelonoidis sombreroensis	0.0117	0.1260	0.06885
## 23		Chelonoidis sp. [Navassa]	0.0117	0.1260	0.06885
## 24		Gopherus donlatoi	0.0117	0.1260	0.06885
## 25		Hesperotestudo equicomes	0.0117	0.1260	0.06885
## 26		Hesperotestudo incisa	0.0117	0.1260	0.06885
## 27		Testudo suttoensis	0.0117	0.1260	0.06885
## 28		Hesperotestudo wilsoni	0.0010	0.1260	0.06350
## 29		Manouria oyamai	0.0010	0.1260	0.06350
## 30		Chelonoidis sp. [Hispaniola]	0.0010	0.1260	0.06350
## 31		Chelonoidis monensis	0.0000	0.1260	0.06300
## 32		Aldabrachelys laetoliensis	0.1260	3.6000	1.86300
## 33		Centrochelys marocana	0.1260	3.6000	1.86300
## 34		Gopherus sp. [Florida]	0.1260	3.6000	1.86300
## 35		Hesperotestudo campester	0.1260	3.6000	1.86300
## 36		Manouria punjabiensis	0.1260	3.6000	1.86300
## 37		Megalochelys atlas	0.1260	3.6000	1.86300

## 38	Megalochelys cautleyi	0.1260	3.6000	1.86300	
## 39	Testudo or Agrionemys ranovi	0.1260	3.6000	1.86300	
## 40	Testudo oughlamensis	0.1260	3.6000	1.86300	
## 41	Testudo pecorinii	0.1260	3.6000	1.86300	
## 42	Testudo transcaucasia	0.1260	3.6000	1.86300	
## 43	Titanochelon sp. [Lesvos]	0.1260	3.6000	1.86300	
## 44	Centrochelys vulcanica	0.1260	3.6000	1.86300	
## 45	Centrochelys burchardi	0.1260	0.7810	0.45350	
## 46	Centrochelys robusta	0.1260	0.7810	0.45350	
## 47	Hesperotestudo bermudae	0.1260	0.7810	0.45350	
## 48	Hesperotestudo mlynarskii	0.1260	0.7810	0.45350	
## 49	Hesperotestudo percrassa	0.1260	0.7810	0.45350	
## 50	Testudo kenitrensis	0.1260	0.7810	0.45350	
## 51	Testudo lunellensis	0.1260	0.7810	0.45350	
## 52	Titatochelon sp. [Ibiza]	0.1260	0.7810	0.45350	
## 53	Hesperotestudo crassicutata	0.7810	0.0117	0.39635	
## 54	Chelonoidis sp. [Curaçao]	0.0117	0.7810	0.39635	
## 55	Gopherus laticaudatus	0.0117	0.7810	0.39635	
## 56	Megalochelys sp. [Timor]	0.0117	0.7810	0.39635	
## 57	Aldabrachelys gigantea daudinii	0.0000	0.0000	0.00000	
## 58	Chelonoidis abingdonii	0.0000	0.0000	0.00000	
## 59	Chelonoidis nigra	0.0000	0.0000	0.00000	
## 60	Chelonoidis phantastica	0.0000	0.0000	0.00000	
## 61	Chelonoidis sp. [Santa Fé]	0.0000	0.0000	0.00000	
## 62	Chylindrapsis inepta	0.0000	0.0000	0.00000	
## 63	Chylindrapsis peltastes	0.0000	0.0000	0.00000	
## 64	Chylindrapsis triserrata	0.0000	0.0000	0.00000	
## 65	Chylindrapsis indica	0.0000	0.0000	0.00000	
## 66	Chylindrapsis vosmaeri	0.0000	0.0000	0.00000	
## 67	Centrochelys atlantica	0.0117	2.5880	1.29985	
## 68	Testudo sellovii	0.0117	2.5880	1.29985	
## 69	Chelonoidis cubensis	0.1000	2.5880	1.34400	
## 70	Titanochelon gymnesica	1.0000	3.6000	2.30000	
## 71	Testudo kalganensis	1.0000	3.6000	2.30000	
##			Age	CL_mean	CL_range n
## 1		Early Pleistocene	107.5		1
## 2		Early Pleistocene	24.0		1
## 3		Early Pleistocene	28.0		1
## 4		Early Pleistocene	23.0		1
## 5		Early Pleistocene	165.0		1
## 6		Early Pleistocene	80.0	80-95	1
## 7		Early Pleistocene	120.0	180-200	1
## 8		Early Pleistocene	175.0		1
## 9		Early Pleistocene	11.0	60-65	1
## 10		Early Pleistocene	90.0		1
## 11		Early Pleistocene	33.0		1
## 12		Early to Late Pleistocene	150.0		1
## 13		Late Holocene	115.0	180-210	1
## 14		Late Holocene	125.0		1
## 15		Late Holocene	47.0		1
## 16		Late Holocene	75.0		1
## 17		Late Holocene	37.5		1
## 18		Late Miocene	192.5	90-100	1
## 19		Late Miocene to Early Pleistocene?	195.0	60-90	1

## 20	Late Neogene; possibly Pliocene to Early Pleistocene	9.0		1
## 21	Late Pleistocene	83.0		1
## 22	Late Pleistocene	95.0		1
## 23	Late Pleistocene	40.0		1
## 24	Late Pleistocene	58.0	35-40	1
## 25	Late Pleistocene	34.0		1
## 26	Late Pleistocene	29.0		1
## 27	Late Pleistocene	20.0		1
## 28	Late Pleistocene to Early Holocene	23.0		1
## 29	Late Pleistocene to Early Holocene	45.0		1
## 30	Late Pleistocene to Early Holocene?	60.0		1
## 31	Late Pleistocene to Late Holocene	50.0	35-40	1
## 32	Late Pliocene to Early Pleistocene	100.0	105-110	1
## 33	Late Pliocene to Early Pleistocene	190.0	18-26	1
## 34	Late Pliocene to Early Pleistocene	22.0		1
## 35	Late Pliocene to Early Pleistocene	100.0		1
## 36	Late Pliocene to Early Pleistocene	90.0	120-125	1
## 37	Late Pliocene to Early Pleistocene	195.0		1
## 38	Late Pliocene to Early Pleistocene	120.0		1
## 39	Late Pliocene to Early Pleistocene	20.0		1
## 40	Late Pliocene to Early Pleistocene	12.0		1
## 41	Late Pliocene to Early Pleistocene	22.5		1
## 42	Late Pliocene to Early Pleistocene	15.0		1
## 43	Late Pliocene to Early Pleistocene	186.0		1
## 44	Late Pliocene to EarlyPleistocene?	62.5		1
## 45	Middle Pleistocene	87.5		1
## 46	Middle Pleistocene	85.0		1
## 47	Middle Pleistocene	50.0		1
## 48	Middle Pleistocene	20.0		1
## 49	Middle Pleistocene	25.0	180-210	1
## 50	Middle Pleistocene	13.0		1
## 51	Middle Pleistocene	27.5	140-190	1
## 52	Middle Pleistocene	52.0	70-90	1
## 53	Middle Pleistocene to Early Holocene	122.5	100-140	1
## 54	Middle to Late Pleistocene	80.0		1
## 55	Middle to Late Pleistocene	37.5		1
## 56	Middle to Late Pleistocene	150.0		1
## 57	Modern	79.0		1
## 58	Modern	98.0		1
## 59	Modern	96.0	27-28	1
## 60	Modern	88.0		1
## 61	Modern	90.0	25-30	1
## 62	Modern	100.0		1
## 63	Modern	46.0		1
## 64	Modern	100.0	22-23	1
## 65	Modern	120.0		1
## 66	Modern	110.0		1
## 67	Pleistocene	40.0		1
## 68	Pleistocene	150.0	110-130	1
## 69	Pleistocene to Early Holocene	90.0	185-200	1
## 70	Pliocene to Early Pleistocene?	120.0		1
## 71	Tertiary; Pliocene to Early Pleistocene?	27.5	48-56	1

The first plot shows mean CI size for each taxon as a single data point, so each data point is one species (in

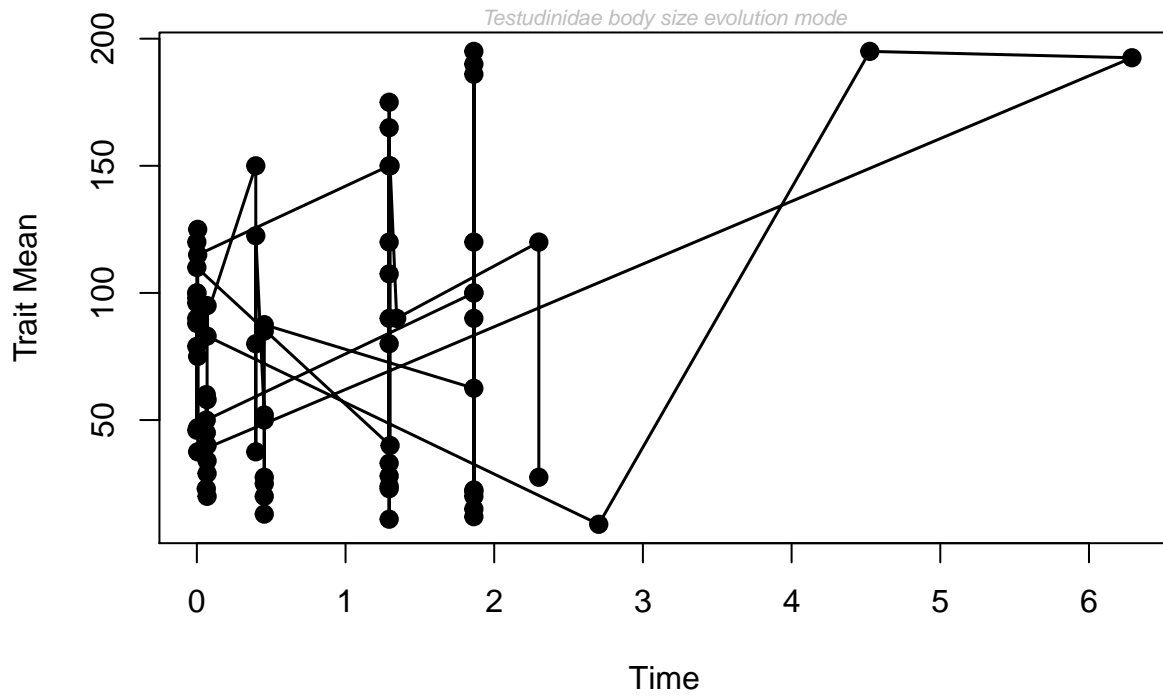
this case this equals one individual, since I don't have sample sizes), even within time bins.

```
Test1 <- test %>%
  mutate(mm = CL_mean, vv=0, nn= n, tt=Age_mean) %>%
  dplyr::select(mm, vv, nn, tt)

paleoTest1 <-as.paleoTS(Test1$mm, Test1$vv, Test1$nn, Test1$tt, MM = NULL,
  genpars = NULL, label = "Testudinidae body size evolution mode")
paleoTest1

## $mm
## [1] 107.5 24.0 28.0 23.0 165.0 80.0 120.0 175.0 11.0 90.0 33.0
## [12] 150.0 115.0 125.0 47.0 75.0 37.5 192.5 195.0 9.0 83.0 95.0
## [23] 40.0 58.0 34.0 29.0 20.0 23.0 45.0 60.0 50.0 100.0 190.0
## [34] 22.0 100.0 90.0 195.0 120.0 20.0 12.0 22.5 15.0 186.0 62.5
## [45] 87.5 85.0 50.0 20.0 25.0 13.0 27.5 52.0 122.5 80.0 37.5
## [56] 150.0 79.0 98.0 96.0 88.0 90.0 100.0 46.0 100.0 120.0 110.0
## [67] 40.0 150.0 90.0 120.0 27.5
##
## $vv
## [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [36] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [71] 0
##
## $nn
## [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [36] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [71] 1
##
## $tt
## [1] 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
## [8] 0.00000 0.00000 0.00000 0.00000 0.00000 -1.28765 -1.28765
## [15] -1.28765 -1.28765 -1.28765 4.99550 3.23250 1.40950 -1.22465
## [22] -1.22465 -1.22465 -1.22465 -1.22465 -1.22465 -1.22465 -1.23000
## [29] -1.23000 -1.23000 -1.23050 0.56950 0.56950 0.56950 0.56950
## [36] 0.56950 0.56950 0.56950 0.56950 0.56950 0.56950 0.56950
## [43] 0.56950 0.56950 -0.84000 -0.84000 -0.84000 -0.84000 -0.84000
## [50] -0.84000 -0.84000 -0.84000 -0.89715 -0.89715 -0.89715 -0.89715
## [57] -1.29350 -1.29350 -1.29350 -1.29350 -1.29350 -1.29350 -1.29350
## [64] -1.29350 -1.29350 -1.29350 0.00635 0.00635 0.05050 1.00650
## [71] 1.00650
##
## $MM
## NULL
##
## $genpars
## NULL
##
## $label
## [1] "Testudinidae body size evolution mode"
##
## $start.age
## [1] 1.2935
##
## $timeDir
```

```
## [1] "increasing"
##
## attr(,"class")
## [1] "paleoTS"
plot(paleoTest1)
```



This is the underlying data for Test1:

```
Test1
```

```
##      mm vv nn      tt
## 1  107.5 0  1 1.29350
## 2   24.0 0  1 1.29350
## 3   28.0 0  1 1.29350
## 4   23.0 0  1 1.29350
## 5  165.0 0  1 1.29350
## 6   80.0 0  1 1.29350
## 7  120.0 0  1 1.29350
## 8  175.0 0  1 1.29350
## 9   11.0 0  1 1.29350
## 10  90.0 0  1 1.29350
## 11  33.0 0  1 1.29350
## 12 150.0 0  1 1.29350
## 13 115.0 0  1 0.00585
## 14 125.0 0  1 0.00585
## 15  47.0 0  1 0.00585
## 16  75.0 0  1 0.00585
```

```

## 17 37.5 0 1 0.00585
## 18 192.5 0 1 6.28900
## 19 195.0 0 1 4.52600
## 20 9.0 0 1 2.70300
## 21 83.0 0 1 0.06885
## 22 95.0 0 1 0.06885
## 23 40.0 0 1 0.06885
## 24 58.0 0 1 0.06885
## 25 34.0 0 1 0.06885
## 26 29.0 0 1 0.06885
## 27 20.0 0 1 0.06885
## 28 23.0 0 1 0.06350
## 29 45.0 0 1 0.06350
## 30 60.0 0 1 0.06350
## 31 50.0 0 1 0.06300
## 32 100.0 0 1 1.86300
## 33 190.0 0 1 1.86300
## 34 22.0 0 1 1.86300
## 35 100.0 0 1 1.86300
## 36 90.0 0 1 1.86300
## 37 195.0 0 1 1.86300
## 38 120.0 0 1 1.86300
## 39 20.0 0 1 1.86300
## 40 12.0 0 1 1.86300
## 41 22.5 0 1 1.86300
## 42 15.0 0 1 1.86300
## 43 186.0 0 1 1.86300
## 44 62.5 0 1 1.86300
## 45 87.5 0 1 0.45350
## 46 85.0 0 1 0.45350
## 47 50.0 0 1 0.45350
## 48 20.0 0 1 0.45350
## 49 25.0 0 1 0.45350
## 50 13.0 0 1 0.45350
## 51 27.5 0 1 0.45350
## 52 52.0 0 1 0.45350
## 53 122.5 0 1 0.39635
## 54 80.0 0 1 0.39635
## 55 37.5 0 1 0.39635
## 56 150.0 0 1 0.39635
## 57 79.0 0 1 0.00000
## 58 98.0 0 1 0.00000
## 59 96.0 0 1 0.00000
## 60 88.0 0 1 0.00000
## 61 90.0 0 1 0.00000
## 62 100.0 0 1 0.00000
## 63 46.0 0 1 0.00000
## 64 100.0 0 1 0.00000
## 65 120.0 0 1 0.00000
## 66 110.0 0 1 0.00000
## 67 40.0 0 1 1.29985
## 68 150.0 0 1 1.29985
## 69 90.0 0 1 1.34400
## 70 120.0 0 1 2.30000

```

```
## 71 27.5 0 1 2.30000
```

For the second plot, I averaged CL means across taxa for each time bin, which leaves one data point per time bin, comprising all taxa within the respective bin:

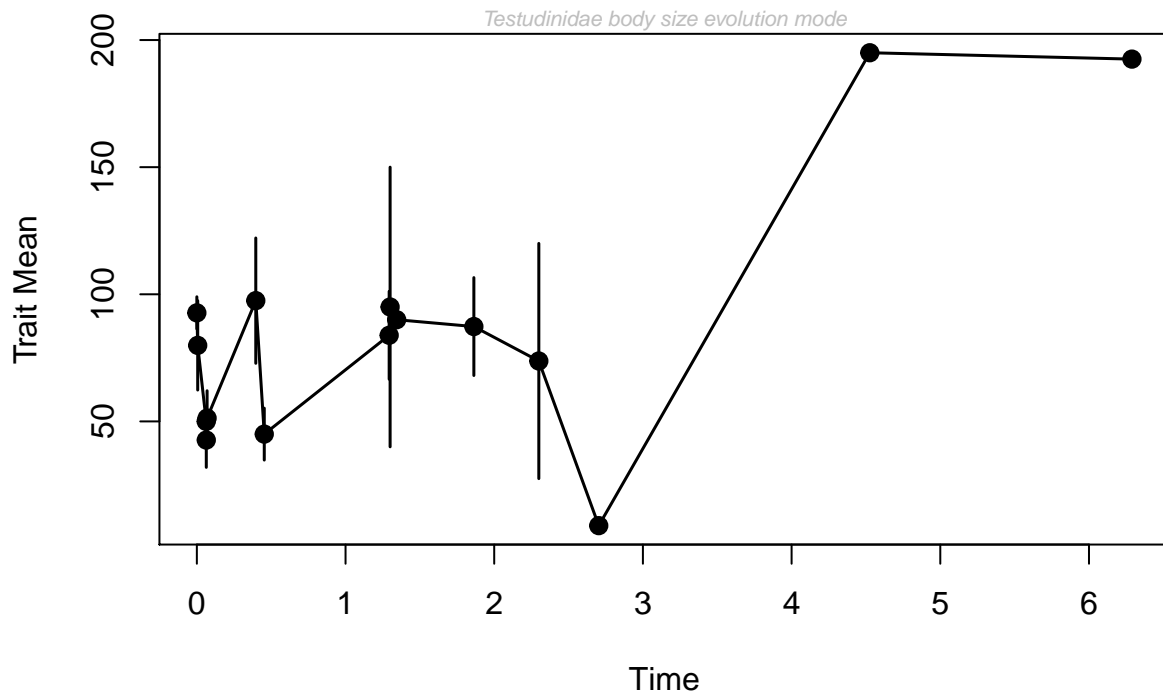
```
Test2 <- test %>%
  group_by(Age_mean) %>%
  summarise(mm = mean(CL_mean), nn=n(), vv=var(CL_mean)) %>%
  mutate(tt=Age_mean) %>%
  dplyr::select(mm, vv, nn, tt)

# NA: column 2, rows 3, 10, 13, 14, 15
Test2[3,2] <- 0
Test2[10,2] <- 0
Test2[13,2] <- 0
Test2[14,2] <- 0
Test2[15,2] <- 0

paleoTest2 <-as.paleoTS(Test2$mm, Test2$vv, Test2$nn, Test2$tt, MM = NULL,
  genpars = NULL, label = "Testudinidae body size evolution mode")
paleoTest2
```

```
## $mm
## [1] 92.70000 79.90000 50.00000 42.66667 51.28571 97.50000 45.00000
## [8] 83.87500 95.00000 90.00000 87.30769 73.75000 9.00000 195.00000
## [15] 192.50000
##
## $vv
## [1] 398.6778 1542.5500 0.0000 346.3333 810.5714 2429.1667 833.6429
## [8] 3589.5511 6050.0000 0.0000 4816.0224 4278.1250 0.0000 0.0000
## [15] 0.0000
##
## $nn
## [1] 10 5 1 3 7 4 8 12 2 1 13 2 1 1 1
##
## $tt
## [1] 0.00000 0.00585 0.06300 0.06350 0.06885 0.39635 0.45350 1.29350
## [9] 1.29985 1.34400 1.86300 2.30000 2.70300 4.52600 6.28900
##
## $MM
## NULL
##
## $genpars
## NULL
##
## $label
## [1] "Testudinidae body size evolution mode"
##
## $start.age
## NULL
##
## $timeDir
## [1] "increasing"
##
## attr(,"class")
```

```
## [1] "paleoTS"
plot(paleoTest2)
```



This is the underlying data for Test2:

```
Test2
```

```
## # A tibble: 15 × 4
##       mm      vv    nn    tt
##   <dbl> <dbl> <int> <dbl>
## 1  92.70000 398.6778    10 0.00000
## 2  79.90000 1542.5500     5 0.00585
## 3  50.00000   0.0000     1 0.06300
## 4  42.66667 346.3333     3 0.06350
## 5  51.28571 810.5714     7 0.06885
## 6  97.50000 2429.1667     4 0.39635
## 7  45.00000 833.6429     8 0.45350
## 8  83.87500 3589.5511    12 1.29350
## 9  95.00000 6050.0000     2 1.29985
## 10 90.00000   0.0000     1 1.34400
## 11 87.30769 4816.0224    13 1.86300
## 12 73.75000 4278.1250     2 2.30000
## 13 9.00000   0.0000     1 2.70300
## 14 195.00000   0.0000     1 4.52600
## 15 192.50000   0.0000     1 6.28900
```


To DO:

- figure out if Checklist data is of any use (means? medians? sample size?) or see if authors can provide necessary data
- do paleoTS analyses with FFB data set
- read Hunt papers (see citations in Catalina's paper 2006, 2008, 2008, 2010; also 2015)
- figure out how to implement phylogeny... well, figure out how to do paleoTS analyses with more than one taxon without pooling everything together (as in Test2)

This is an R Markdown Notebook. When you execute code within the notebook, the results appear beneath the code.

Try executing this chunk by clicking the *Run* button within the chunk or by placing your cursor inside it and pressing *Ctrl+Shift+Enter*.

Add a new chunk by clicking the *Insert Chunk* button on the toolbar or by pressing *Ctrl+Alt+I*.

When you save the notebook, an HTML file containing the code and output will be saved alongside it (click the *Preview* button or press *Ctrl+Shift+K* to preview the HTML file).