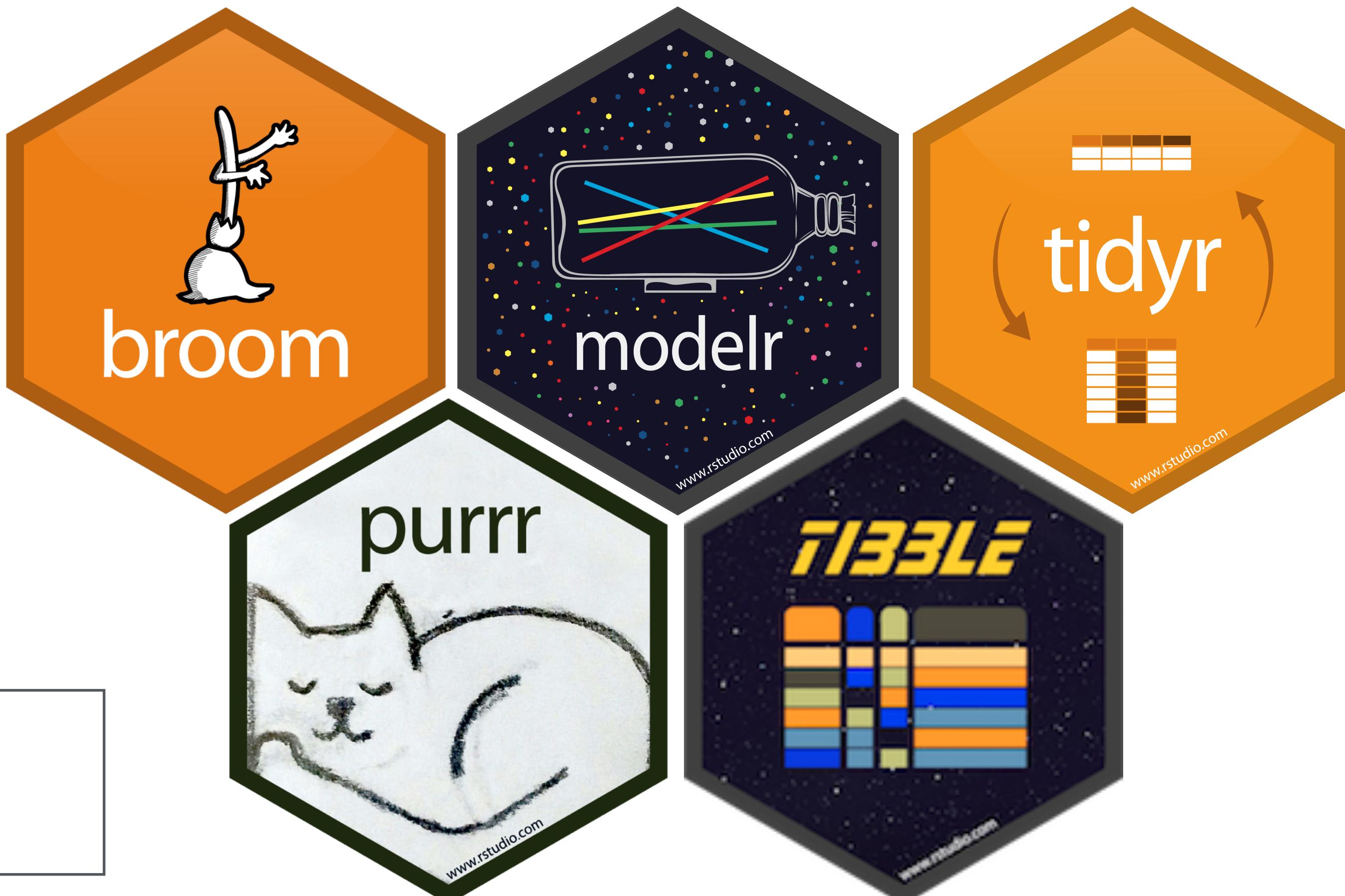


Organize with list columns



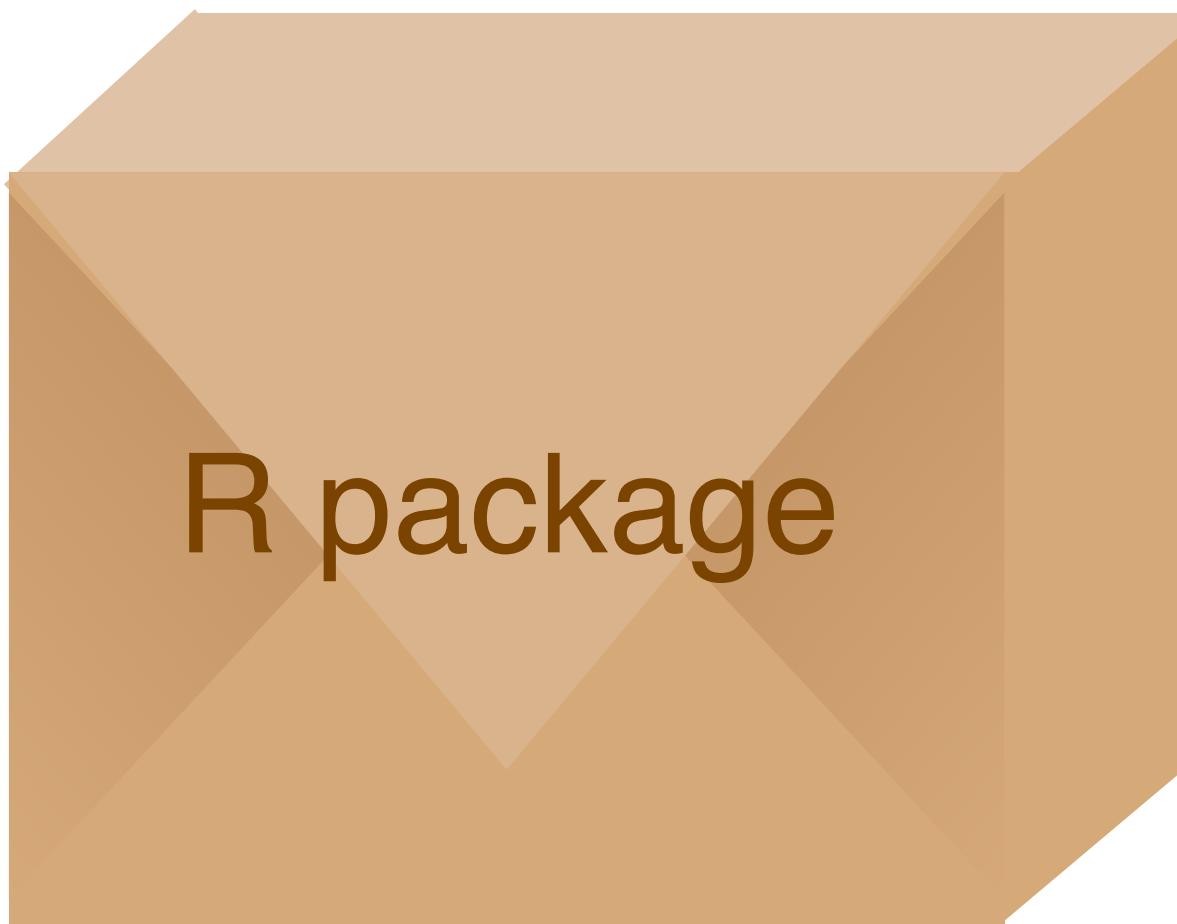
In R4DS

Many Models

Your Turn

Open **08-Organize.Rmd**

gapminder



A subset of the data available at Hans
Rosling's gapminder.org

```
# install.packages("gapminder")  
library(gapminder)
```

gapminder

country <fctr>	continent <fctr>	year <int>	lifeExp <dbl>	pop <int>	gdpPerCap <dbl>
Afghanistan	Asia	1952	28.80100	8425333	779.4453
Afghanistan	Asia	1957	30.33200	9240934	820.8530
Afghanistan	Asia	1962	31.99700	10267083	853.1007
Afghanistan	Asia	1967	34.02000	11537966	836.1971
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Afghanistan	Asia	1992	41.67400	16317921	649.3414
Afghanistan	Asia	1997	41.76300	22227415	635.3414

1-10 of 1,704 rows

Previous 1 2 3 4 5 6 ... 100 Next

Your Turn 1

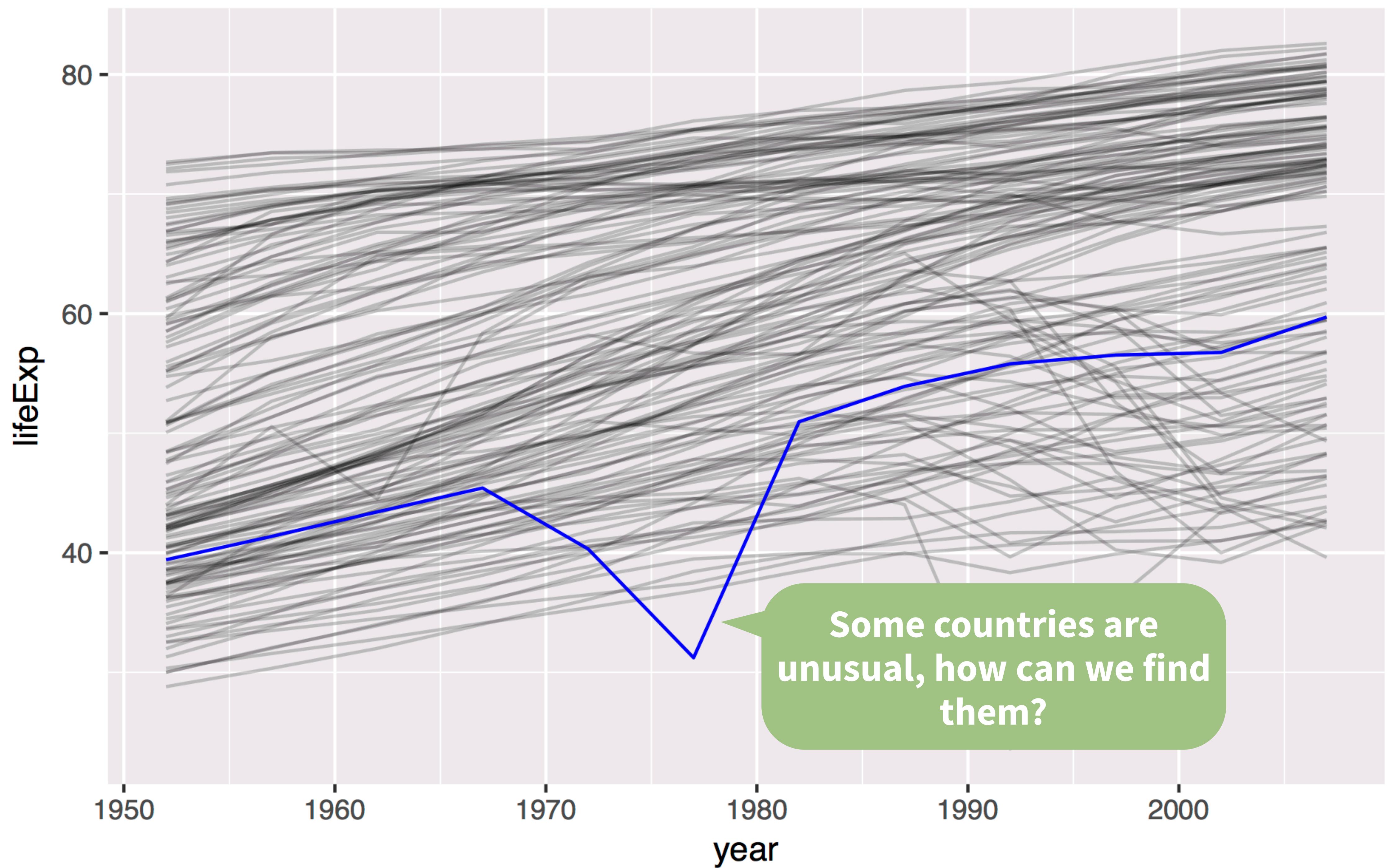
How has life expectancy changed over time?

Make a line plot of **lifeExp** vs. **year** grouped by **country**. Set alpha to 0.2, to see the results better.



```
gapminder %>%  
  ggplot(mapping = aes(x = year, y = lifeExp, group = country)) +  
  geom_line(alpha = 0.2)
```

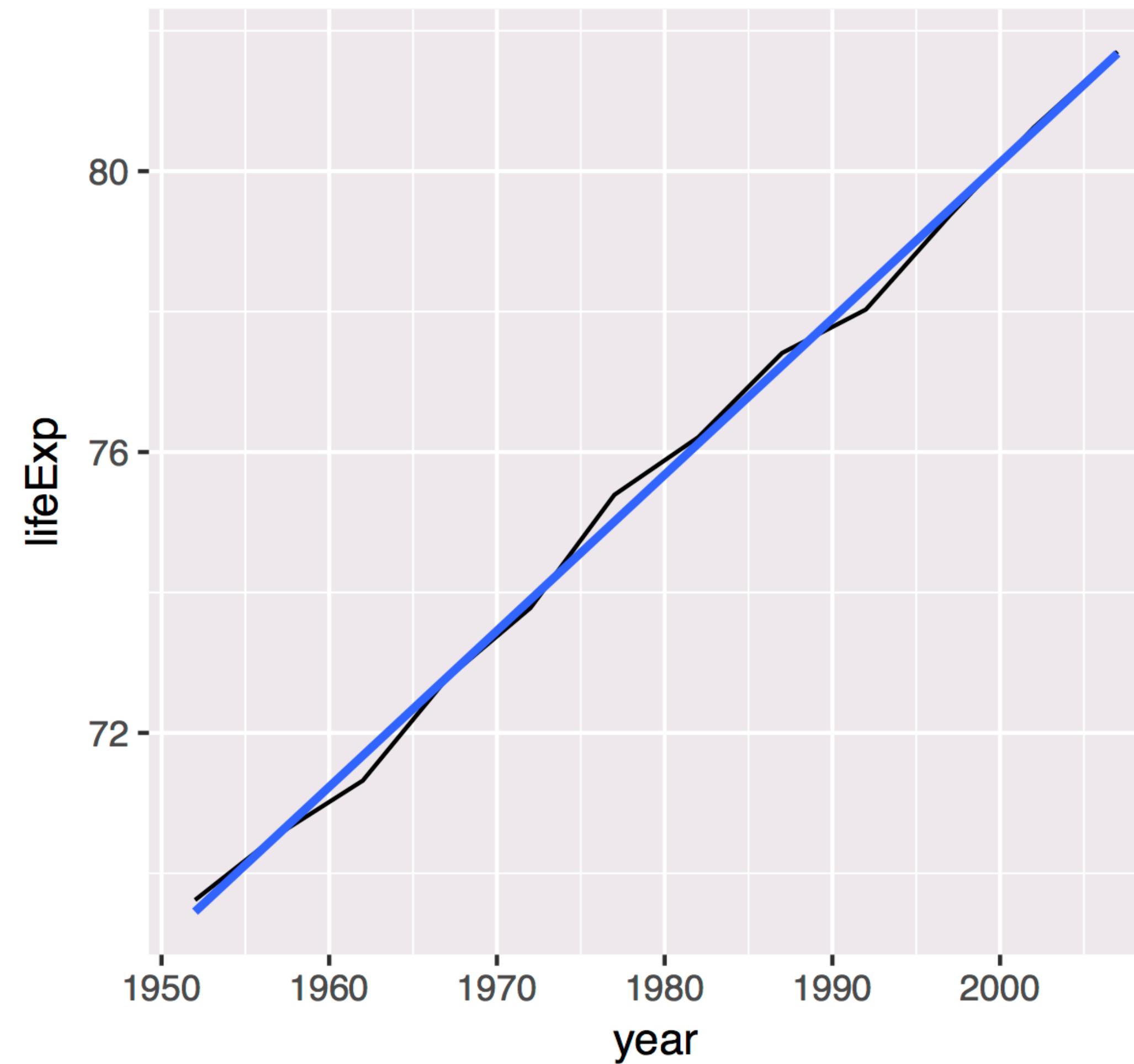




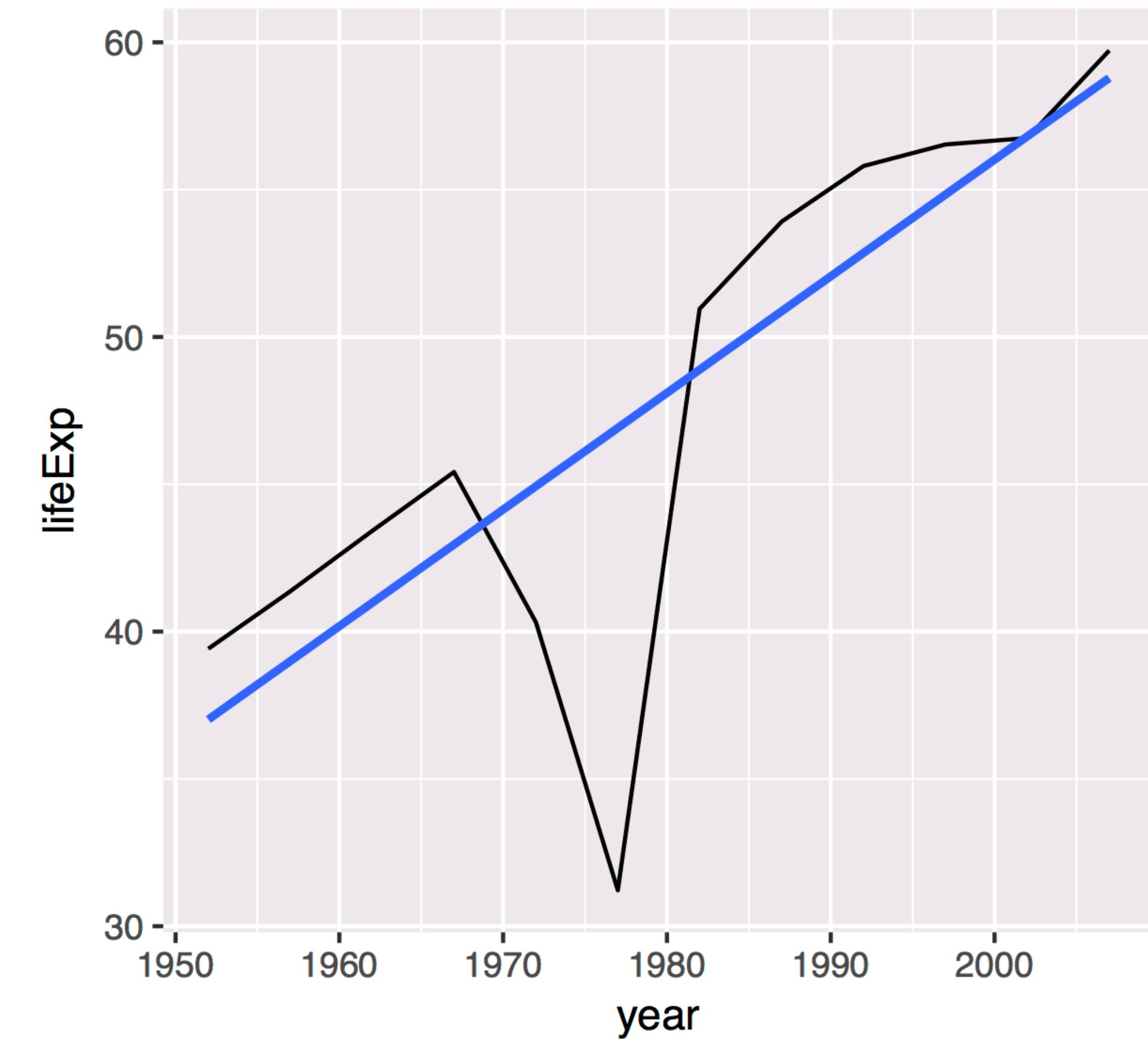
Idea 1

To quantify "linearity," fit a linear model, compare **r-squared**.

Switzerland, R Squared = 0.99



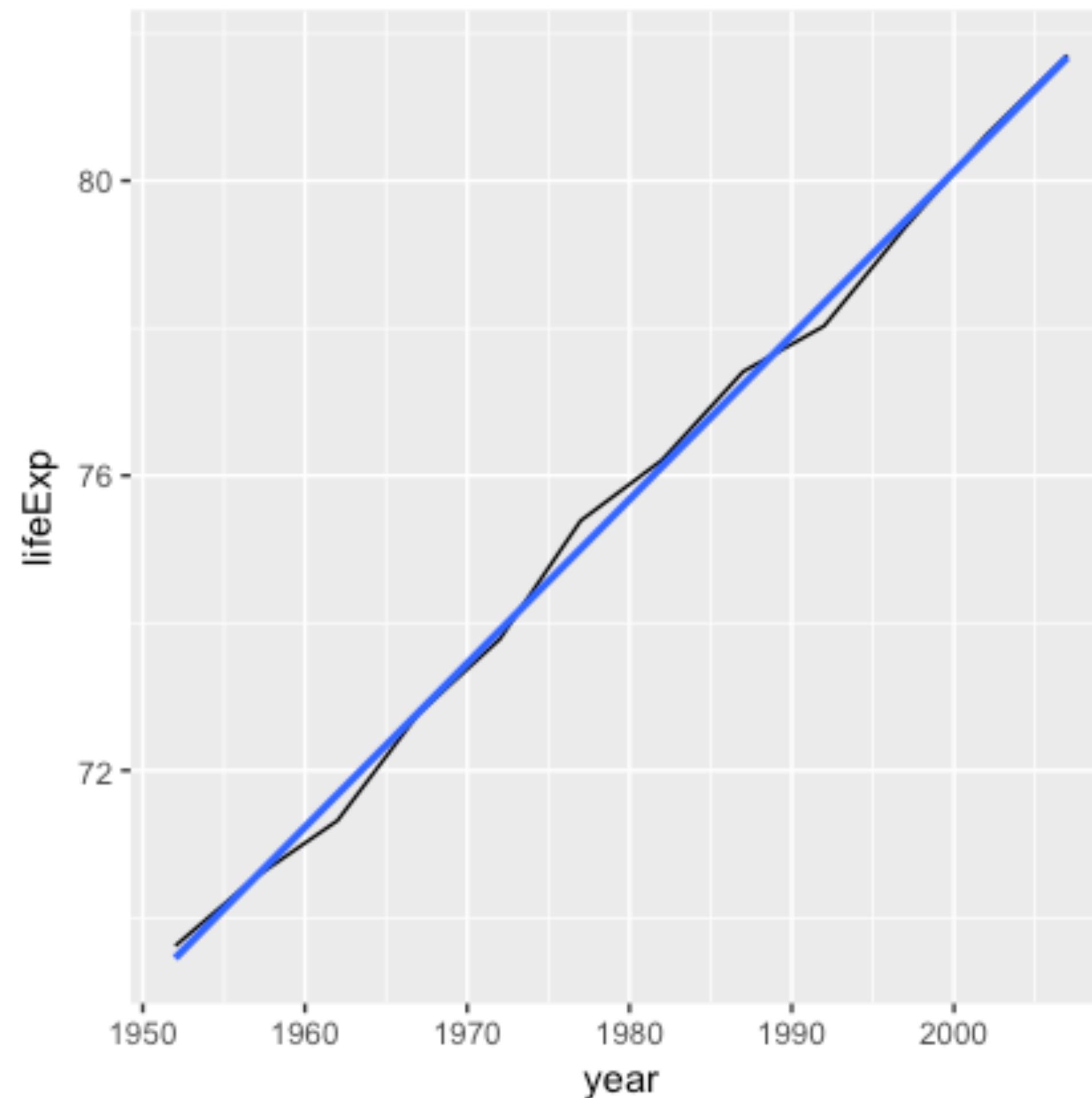
Cambodia, R Squared = 0.63



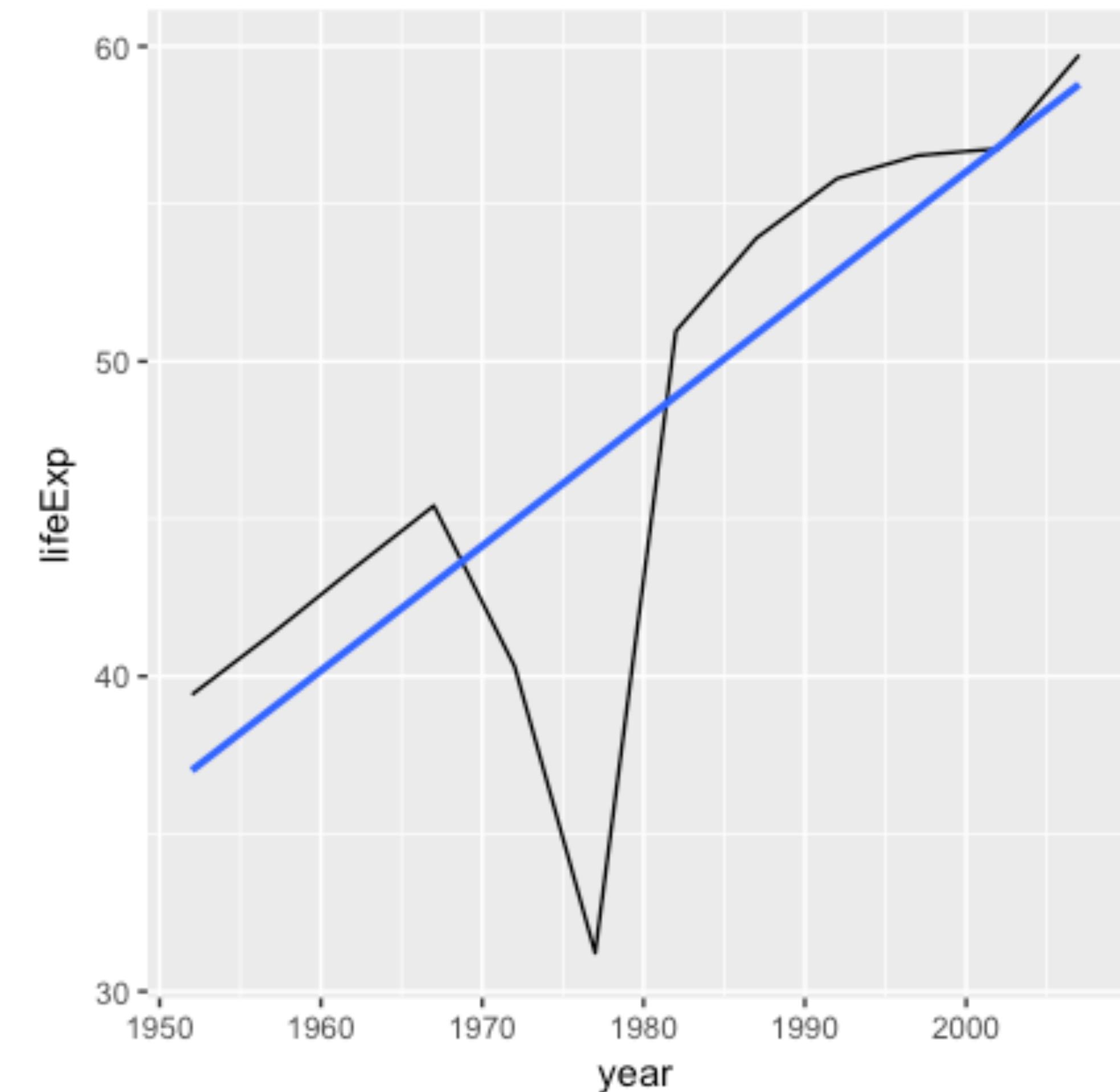
Idea 2

To quantify rate of change fit a linear model, extract **coefficient on year**.

Switzerland = 0.22 years/year



Cambodia = 0.40 years/year



Goal

Fit model, compute r.squared, collect coefficient ***for every country.***

1. **dplyr + tidyverse** grouping toolkit
2. **purrr** toolkit and list columns

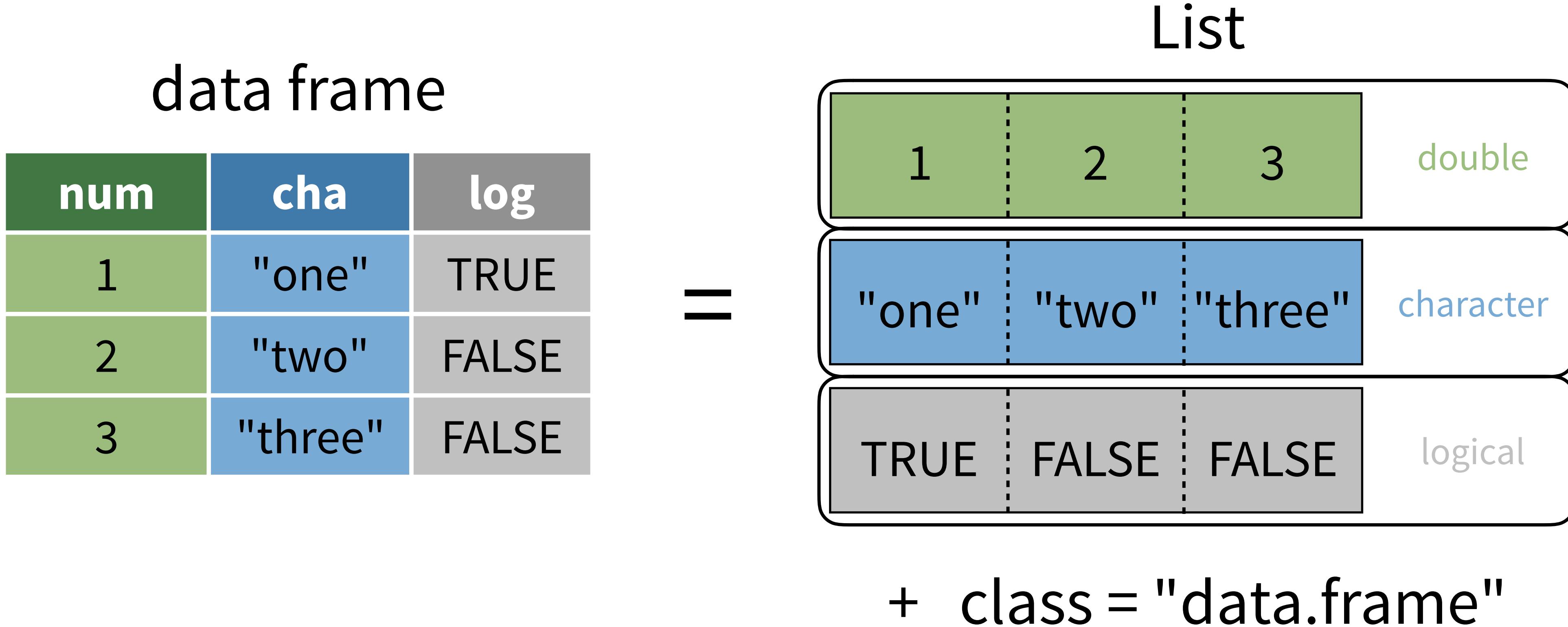
list columns

R

Quiz

How is a data frame/tibble similar to a list?

A data frame / tibble is a list



A data frame / tibble is a list

data frame

num	cha	log
1	"one"	TRUE
2	"two"	FALSE
3	"three"	FALSE

`df["num"]`

num
1
2
3

`df[["num"]]`

`df$num`

`c(1, 2, 3)`

A data frame / tibble is a list

data frame

num	cha	log
1	"one"	TRUE
2	"two"	FALSE
3	"three"	FALSE

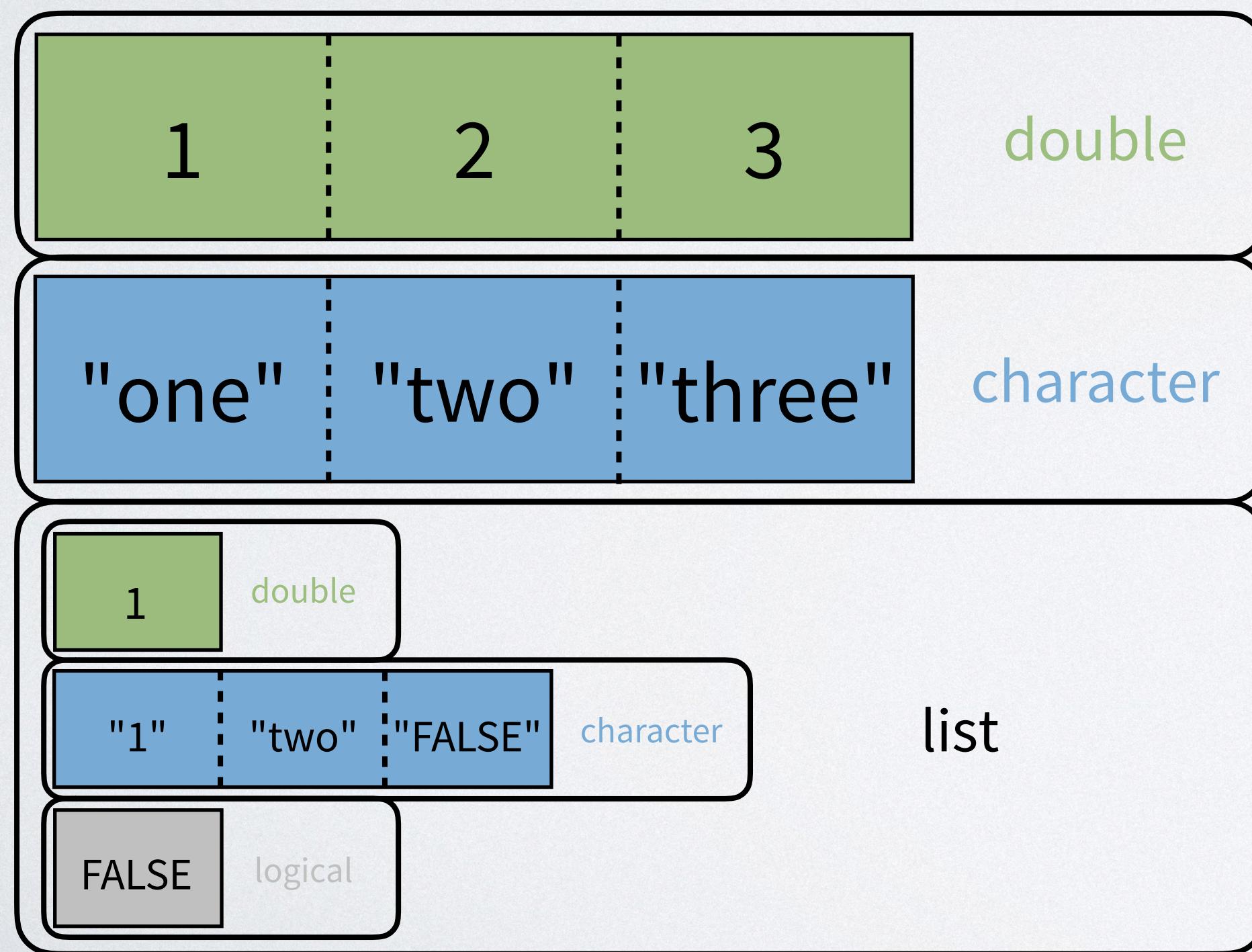
df %>% select(num)

num
1
2
3

Consider

If one of the elements of a list can be another list,
can one of the columns of a data frame be another list?

List



?
=

data frame

num	cha	listcol
1	"one"	1
2	"two"	c("1", "two", "FALSE")
3	"three"	FALSE

Yes.

```
tibble(  
  num = c(1, 2, 3),  
  cha = c("one", "two", "three"),  
  listcol = list(1, c("1", "two", "FALSE"), FALSE)  
)
```

num <code><dbl></code>	cha <code><chr></code>	listcol <code><list></code>
1	one	<code><dbl [1]></code>
2	two	<code><chr [3]></code>
3	three	<code><lgl [1]></code>
3 rows		



Goal

country	data	model																																																																																																								
Afghanistan	<p>Each element in this column is a tibble</p> <table border="1"> <thead> <tr> <th>continent</th><th>year</th><th>lifeExp</th><th>pop</th><th>gdpPerCap</th></tr> </thead> <tbody> <tr><td>Asia</td><td>1952</td><td>28.301</td><td>8425333</td><td>779.4453</td></tr> <tr><td>Asia</td><td>1957</td><td>30.332</td><td>9240934</td><td>820.8530</td></tr> <tr><td>Asia</td><td>1962</td><td>31.997</td><td>10267083</td><td>853.1007</td></tr> <tr><td>Asia</td><td>1967</td><td>34.220</td><td>11537966</td><td>836.1971</td></tr> <tr><td>Asia</td><td>1972</td><td>36.88</td><td>13079460</td><td>739.9811</td></tr> <tr><td>Asia</td><td>1977</td><td>38.38</td><td>14880372</td><td>786.1134</td></tr> <tr><td></td><td></td><td>12881816</td><td>978.0114</td><td></td></tr> <tr><td></td><td></td><td>13867957</td><td>852.3959</td><td></td></tr> <tr><td></td><td></td><td>16317921</td><td>649.3414</td><td></td></tr> <tr><td></td><td></td><td>22227415</td><td>635.3414</td><td></td></tr> <tr><td></td><td></td><td>25268405</td><td>726.7341</td><td></td></tr> <tr><td></td><td></td><td>31889923</td><td>974.5803</td><td></td></tr> </tbody> </table> <table border="1"> <thead> <tr> <th></th><th>pop</th><th>gdpPerCap</th></tr> </thead> <tbody> <tr><td>Europe</td><td>1282697</td><td>1601.056</td></tr> <tr><td>Europe</td><td>1957</td><td>59.280</td></tr> <tr><td>Europe</td><td>1962</td><td>64.820</td></tr> <tr><td>Europe</td><td>1967</td><td>66.220</td></tr> <tr><td>Europe</td><td>1972</td><td>67.690</td></tr> <tr><td>Europe</td><td>1977</td><td>68.930</td></tr> <tr><td>Europe</td><td>1982</td><td>70.420</td></tr> <tr><td>Europe</td><td>1987</td><td>72.000</td></tr> <tr><td>Europe</td><td>1992</td><td>71.581</td></tr> <tr><td>Europe</td><td>1997</td><td>72.950</td></tr> <tr><td>Europe</td><td>2002</td><td>75.651</td></tr> <tr><td>Europe</td><td>2007</td><td>76.423</td></tr> </tbody> </table>	continent	year	lifeExp	pop	gdpPerCap	Asia	1952	28.301	8425333	779.4453	Asia	1957	30.332	9240934	820.8530	Asia	1962	31.997	10267083	853.1007	Asia	1967	34.220	11537966	836.1971	Asia	1972	36.88	13079460	739.9811	Asia	1977	38.38	14880372	786.1134			12881816	978.0114				13867957	852.3959				16317921	649.3414				22227415	635.3414				25268405	726.7341				31889923	974.5803			pop	gdpPerCap	Europe	1282697	1601.056	Europe	1957	59.280	Europe	1962	64.820	Europe	1967	66.220	Europe	1972	67.690	Europe	1977	68.930	Europe	1982	70.420	Europe	1987	72.000	Europe	1992	71.581	Europe	1997	72.950	Europe	2002	75.651	Europe	2007	76.423	<pre>Call: lm(formula = lifeExp ~ year, data = .x) Coefficients: (Intercept) year -594.0725 0.3347</pre>
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continent	year	lifeExp	pop	gdpPerCap
Africa	1952	43.077	9279525	2449.008

Call:

nesting



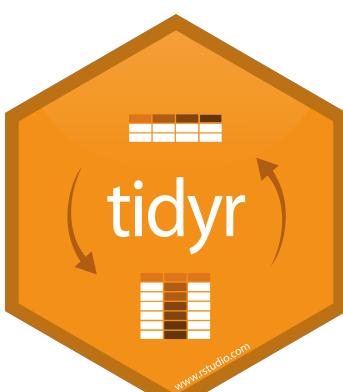
nest()

Nest rows into a list column by group.

```
nest(data, .key = "data")
```

A grouped
data frame

name for the new
list column



Places grouped cases into a list column.

```
gapminder %>%  
  group_by(country) %>%  
  nest()
```

country

Afghanistan

Albania

data

continent	year	lifeExp	pop	gdpPercap
Asia	1952	28.801	8425333	779.4453
Asia	1957	30.332	9240934	820.8530
Asia	1962	31.997	10267083	853.1007
Asia	1967	34.020	11537966	836.1971
Asia	1972	36.088	13079460	739.9811
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Asia	2007	43.828	31889923	974.5803

continent	year	lifeExp	pop	gdpPercap
Europe	1952	55.230	1282697	1601.056
Europe	1957	59.280	1476505	1942.284
Europe	1962	64.820	1728137	2312.889
Europe	1967	66.220	1984060	2760.197
Europe	1972	67.690	2263554	3313.422
Europe	1977	68.930	2509048	3533.004
Europe	1982	70.420	2780097	3630.881
Europe	1987	72.000	3075321	3738.933
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Europe	2007	76.423	3600523	5937.030

continent	year	lifeExp	pop	gdpPercap

gapminder

country <fctr>	continent <fctr>	year <int>	lifeExp <dbl>	pop <int>	gdpPercap <dbl>
Afghanistan	Asia	1952	28.80100	8425333	779.4453
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1-10 of 1,704 rows

Previous 1 2 3 4 5 6 ... 100 Next

```
gapminder_nested <- gapminder %>%  
  group_by(country) %>%  
  nest()
```



country	data
<fctr>	<list>
Afghanistan	<tibble>
Albania	<tibble>
Algeria	<tibble>
Angola	<tibble>
Argentina	<tibble>
Australia	<tibble>
Austria	<tibble>
Bahrain	<tibble>
Bangladesh	<tibble>
Belgium	<tibble>

gapminder_nested\$data[[1]]

country
<fctr>

Afghanistan

Albania

Algeria

Angola

Argentina

Australia

Austria

Bahrain

Bangladesh

Belgium

data
<list>

<tibble>

continent <fctr>	year <int>	lifeExp <dbl>	pop <int>	gdpPercap <dbl>
Asia	1952	28.801	8425333	779.4453
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Asia	1992	41.674	16317921	649.3414
Asia	1997	41.763	22227415	635.3414

1-10 of 12 rows

Previous 1 2 Next

1-10 of 142 rows

Previous 1 2 3 4 5 6 ... 15 Next

```
fit_model <- function(df) lm(lifeExp ~ year, data = df)

gapminder_nested <- gapminder_nested %>%
  mutate(model = map(data, fit_model))
```

country
<fctr>

Afghanistan

Albania

Algeria

Angola

Argentina

Australia

Austria

Bahrain

Bangladesh

Belgium

map()
takes a list

data
<list>

<tibble>

model
<list>

<S3: lm>

...and
returns a list

gapminder_nested\$model[[1]]

country	data	model
<fctr>	<list>	<list>
Afghanistan	<tibble>	<S3: lm>
Albania	<tibble>	<S3: lm>
Algeria	<tibble>	<S3: lm>
Angola	<tibble>	<S3: lm>
Argentina	<tibble>	<S3: lm>
Australia	<tibble>	<S3: lm>
Austria	<tibble>	<S3: lm>
Bahrain	<tibble>	<S3: lm>
Bangladesh	<tibble>	<S3: lm>
Belgium	<tibble>	<S3: lm>

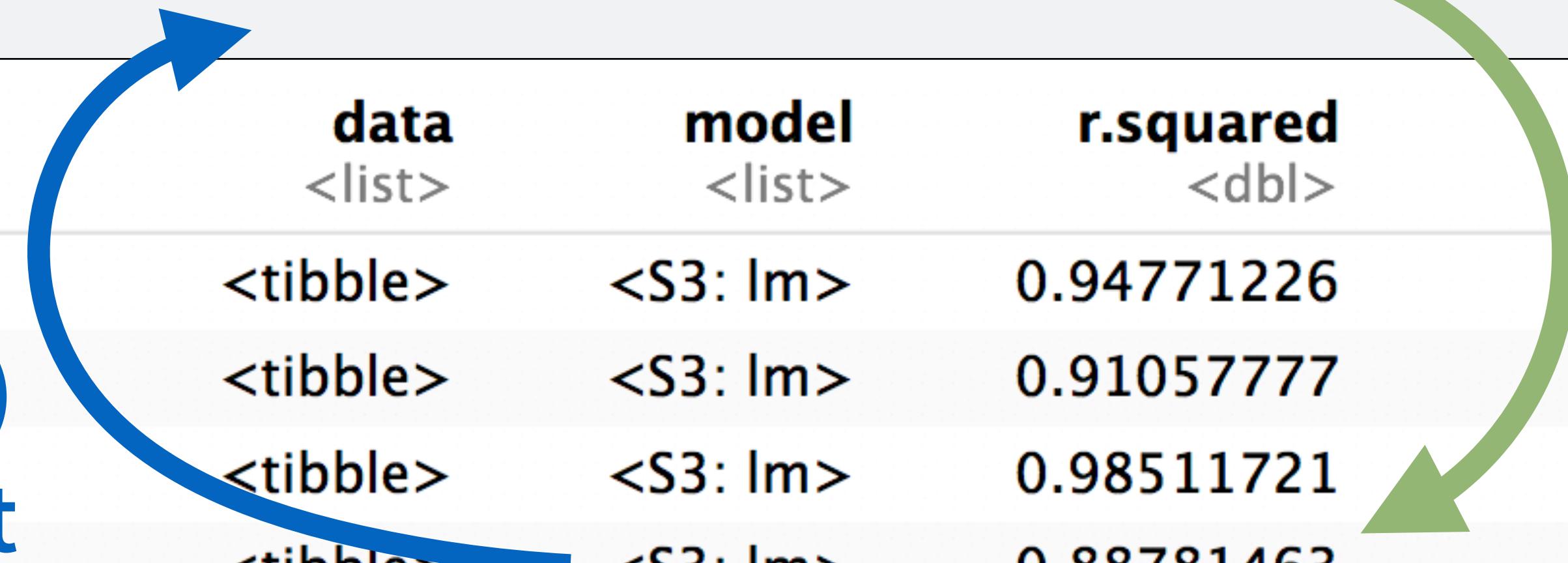
```
Call:  
lm(formula = lifeExp ~ year, data = x)  
  
Coefficients:  
(Intercept)          year  
-507.5343           0.2753
```

```
get_rsq <- function(mod) glance(mod)$r.squared
```

```
gapminder_nested <- gapminder_nested %>%  
  mutate(r.squared = map dbl(model, get_rsq))
```

country	data	model	r.squared
<fctr>	<list>	<list>	<dbl>
Afghanistan	<tibble>	<S3: lm>	0.94771226
Albania	<tibble>	<S3: lm>	0.91057777
Algeria	<tibble>	<S3: lm>	0.98511721
Angola	<tibble>	<S3: lm>	0.88781463
Argentina	<tibble>	<S3: lm>	0.99556810
Australia	<tibble>	<S3: lm>	0.97964774
Austria	<tibble>	<S3: lm>	0.99213401
Bahrain	<tibble>	<S3: lm>	0.96673981
Bangladesh	<tibble>	<S3: lm>	0.98936087
Belgium	<tibble>	<S3: lm>	0.99454056

map dbl()
takes a list



...and
returns a
number

Your Turn 2

Run the chunk then,
filter `gapminder_nested` to find the countries with
`r.squared` less than 0.5.

```
gapminder_nested %>%  
  filter(r.squared < 0.5)
```

But how can we plot
these?

country	data	model	r.squared
Botswana	<tibble>	<S3: lm>	0.03402340
Central African Republic	<tibble>	<S3: lm>	0.49324448
Congo, Dem. Rep.	<tibble>	<S3: lm>	0.34820278
Cote d'Ivoire	<tibble>	<S3: lm>	0.28337240
Kenya	<tibble>	<S3: lm>	0.44255729
Lesotho	<tibble>	<S3: lm>	0.08485635
Namibia	<tibble>	<S3: lm>	0.43702163
Rwanda	<tibble>	<S3: lm>	0.01715964
South Africa	<tibble>	<S3: lm>	0.31246865
Swaziland	<tibble>	<S3: lm>	0.06821087

unnest()

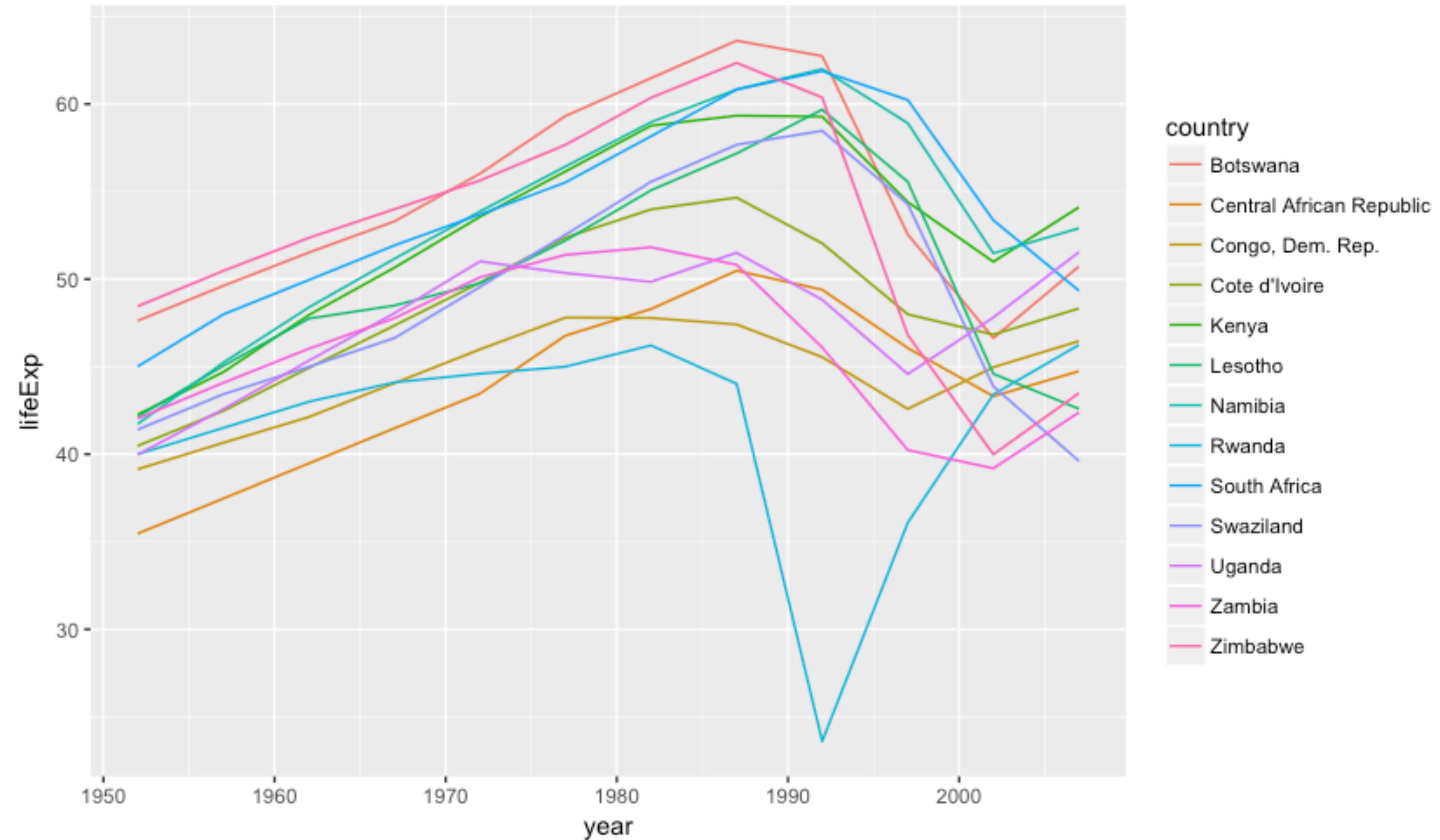
```
poor_fit <- gapminder_nested %>%  
  filter(r.squared < 0.5)  
  
gapminder_nested %>% unnest(data)
```

Column to unnest

country <fctr>	r.squared <dbl>	continent <fctr>	year <int>	lifeExp <dbl>	pop <int>
Botswana	0.03402340	Africa	1952	47.622	442308
Botswana	0.03402340	Africa	1957	49.618	474639
Botswana	0.03402340	Africa	1962	51.520	512764
Botswana	0.03402340	Africa	1967	53.298	553541
Botswana	0.03402340	Africa	1972	56.024	619351

Columns from
inside data

```
unnest(poor_fit, data) %>%  
  ggplot(aes(x = year, y = lifeExp)) +  
  geom_line(aes(color = country))
```



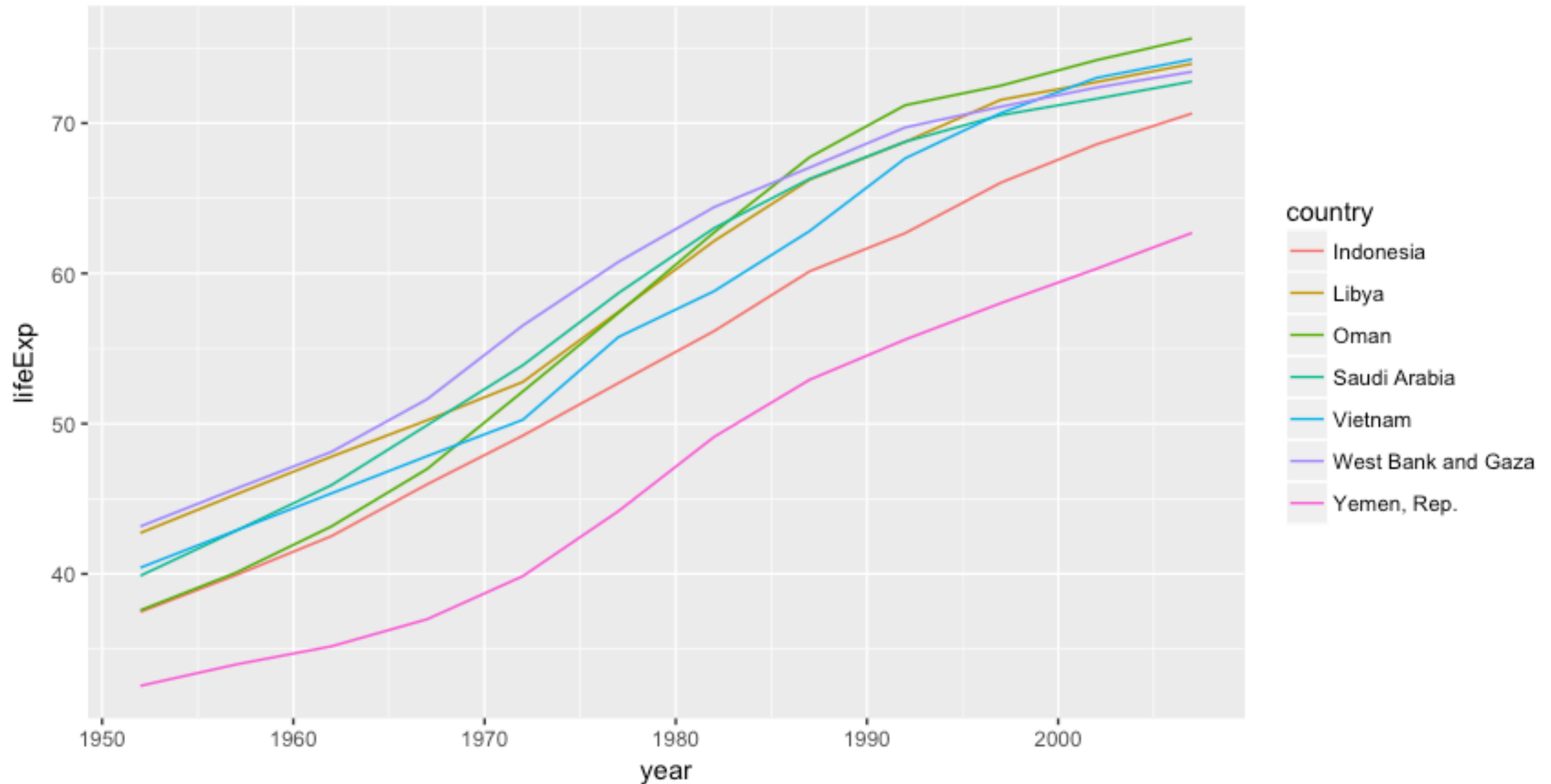
Your Turn 3

Edit the code in the chunk provided to instead find and plot countries with a slope above 0.6 years/year.

I've provided a `get_slope()` function:

```
get_slope <- function(mod) {  
  tidy(mod) %>% filter(term == "year") %>% pull(estimate)  
}
```

```
gapminder_nested <- gapminder_nested %>%  
  mutate(slope = map dbl(model, get_slope))  
  
big_slope <- gapminder_nested %>%  
  filter(slope > 0.6)  
  
unnest(big_slope, data) %>%  
  ggplot(aes(x = year, y = lifeExp)) +  
  geom_line(aes(color = country))
```



Take Away

A table is ...an organizational structure ...that you can manipulate.

country	r.squared	data	model																										
Botswana	0.03	<table border="1"> <thead> <tr> <th>year</th><th>.resid</th></tr> </thead> <tbody> <tr><td>1952</td><td>-5.3071154</td></tr> <tr><td>1957</td><td>-3.6144580</td></tr> <tr><td>1962</td><td>-2.0158007</td></tr> <tr><td>1967</td><td>-0.5411434</td></tr> <tr><td>1972</td><td>1.8815140</td></tr> <tr><td>1977</td><td>4.8731713</td></tr> <tr><td>1982</td><td>6.7348287</td></tr> <tr><td>1987</td><td>8.5694860</td></tr> <tr><td>1992</td><td>7.3891434</td></tr> <tr><td>1997</td><td>-3.1031993</td></tr> <tr><td>2002</td><td>-9.3285420</td></tr> <tr><td>2007</td><td>-5.5378846</td></tr> </tbody> </table>	year	.resid	1952	-5.3071154	1957	-3.6144580	1962	-2.0158007	1967	-0.5411434	1972	1.8815140	1977	4.8731713	1982	6.7348287	1987	8.5694860	1992	7.3891434	1997	-3.1031993	2002	-9.3285420	2007	-5.5378846	<pre> Call: lm(formula = lifeExp ~ year, data = .) Coefficients: (Intercept) year -65.49586 0.06067 </pre>
year	.resid																												
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Lesotho	0.08	<table border="1"> <thead> <tr> <th>year</th><th>.resid</th></tr> </thead> <tbody> <tr><td>1952</td><td>-5.2410256</td></tr> <tr><td>1957</td><td>-2.8098543</td></tr> <tr><td>1962</td><td>-0.5876830</td></tr> <tr><td>1967</td><td>-0.3205117</td></tr> <tr><td>1972</td><td>0.4766597</td></tr> <tr><td>1977</td><td>2.4398310</td></tr> <tr><td>1982</td><td>4.8320023</td></tr> <tr><td>1987</td><td>6.4561737</td></tr> <tr><td>1992</td><td>8.4833450</td></tr> <tr><td>1997</td><td>3.8785163</td></tr> <tr><td>2002</td><td>-7.5643124</td></tr> <tr><td>2007</td><td>-10.0431410</td></tr> </tbody> </table>	year	.resid	1952	-5.2410256	1957	-2.8098543	1962	-0.5876830	1967	-0.3205117	1972	0.4766597	1977	2.4398310	1982	4.8320023	1987	6.4561737	1992	8.4833450	1997	3.8785163	2002	-7.5643124	2007	-10.0431410	<pre> Call: lm(formula = lifeExp ~ year, data = .) Coefficients: (Intercept) year -139.16529 0.09557 </pre>
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1997	3.8785163																												
2002	-7.5643124																												
2007	-10.0431410																												

Benefits

Data and models stay in correspondence across manipulations

```
gapminder_nested %>% filter(str_sub(country, 1, 1) == "P")
```

country	data	model	r.squared	slope
Pakistan	<tibble>	<S3: lm>	0.9972497	0.4057923
Panama	<tibble>	<S3: lm>	0.9511952	0.3542091
Paraguay	<tibble>	<S3: lm>	0.9829865	0.1573545
Peru	<tibble>	<S3: lm>	0.9884740	0.5276979
Philippines	<tibble>	<S3: lm>	0.9914226	0.4204692
Poland	<tibble>	<S3: lm>	0.8396631	0.1962189
Portugal	<tibble>	<S3: lm>	0.9690351	0.3372014
Puerto Rico	<tibble>	<S3: lm>	0.9078191	0.2105748

8 rows

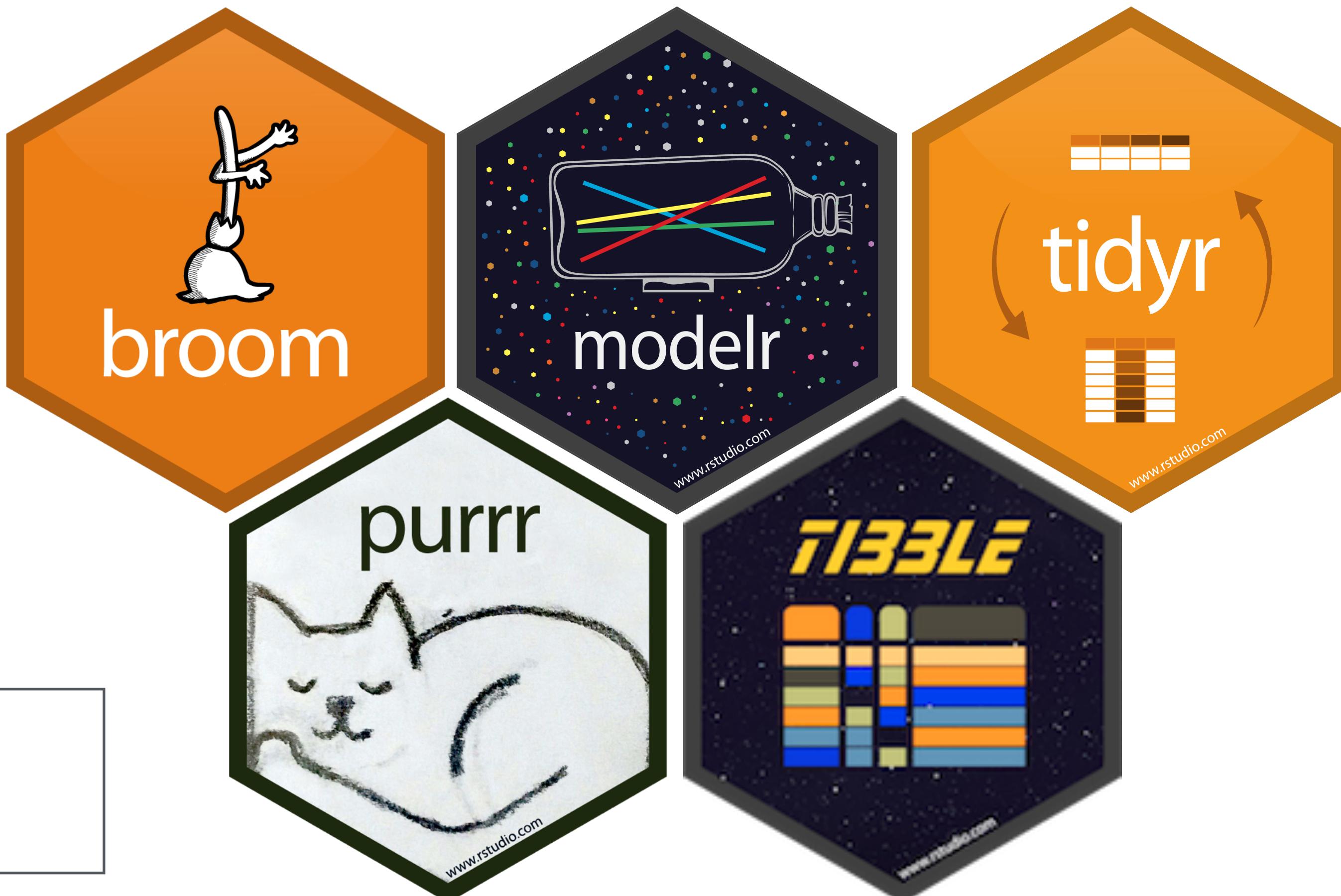
Your Turn 4

Challenge:

1. Create your own copy of `gapminder_nested` and then add one more list column: **output** which contains the output of **augment()** for each model.
2. Plot the residuals against time for the countries with large r-squared.



Organize with list columns



In R4DS

Many Models