## **R/Insurance Webinars** Jan 2024

For the R Consortium's R/Adoption Series

## Welcome

- 1. From Excel to programming in R (today's topic)
- 2. From programming in R to putting R into production
- 3. R performance culture
- 4. High performance programming in R

Delivered on behalf of the R Consortium by Georgios Bakoloukas and Benedikt Schamberger, Actuarial Control, Group Risk Management, Swiss Re

## Background

- Swiss Re internal R community sponsored by our Group Chief Actuary Philip Long (Atelier programme)
- 2000+ community with 500+ regular coders who also support each other
- The case we see today appeared in our Microsoft Teams community channel by an actuary in a high-growth market
- Views expressed belong solely to the speakers and not necessarily to the speaker's employer

## Running example for webinars 1 & 2

- Insurer covers the remaining balance of loans in case of death/disability of the borrower
- Requires a quote for a portfolio of caa. 300,000 policies
- Has provided information on a) loan amount b) loan duration and c) interest rate for each policy
- Problem: The actuary needs to calculate the sum-insured profile for each policy as it amortises
- A solution in Excel and a potential solution in R

## A credit life insurance quote

Lan Amount         1,000         Monthly cashforws         Interest         Principal         Balance - BoP         Transmith         Transmith         Balance - BoP         Transmith         Transmith         Transmith         Balance - BoP         Transmith         Transmith <thtransmith< th=""> <thtransmith< th="">         &lt;</thtransmith<></thtransmith<>	Data input Modellin		Modelling and or	Aodelling and output							
Lan Term (in years)       3       Time-months)       Balance - BoP       Interest       Pincipal       Balance - EoP       Time-years         Lan Term (in months)       3       976.07       8.13       2.243       976.07       1.00         Parameter input       3       981.93       7.93       2.433       927.00       1         Interest Rate (Annual Percentage Rate)       10%       4       927.00       7.73       2.444       985.33       1         Interest Rate (Annual Percentage Rate)       0.83%       5       903.06       7.53       2.447       885.37       1       1         Modelling and Output       5       987.027       9       882.82       6.60       25.58       777.27       1<	Loan Amount	1,000	Monthly cashflor	Monthly cashflows							
Laan Term (in months)       36       1       1,000.00       8.33       23.93       976.07       1         Parameter input       3       9976.07       813       24.13       9951.93       11         Interest Rate (Annual Percentage Rate)       00%       4       927.60       7.73       24.54       9903.06       11         Monthly interest rate       0.83%       6       927.60       7.73       24.54       987.82       11         Modeling and Output       6       878.32       7.32       24.96       883.37       1         Equivalent monthly payment       6       878.32       7.52       24.96       883.37       1         Equivalent monthly payment       1       7       683.37       7.11       25.16       828.22       1         Total Payments       1,161.62       10       777.27       6.48       26.79       771.48       1         Total Payments       1,161.62       11       775.48       6.06       26.26       690.26       1         Key       161.62       11       775.48       6.06       26.44       672.82       2       2         Juputs       161.62       11       775.9       13       264.8	Loan Term (in years)	3	Time-months	Balance - BoP	Interest	Principal	Balance - EoP	Time-years			
Parameter input Parameter inp	Loan Term (in months)	36	1	1,000.00	8.33	23.93	976.07	1			
Parameter input       3       961 39       7.93       24.33       927.60       1         Interest Rate (Annual Percentage Rate)       10%       4       927.60       7.73       24.64       903.06       1         Monthly interest rate       0.83%       6       903.06       7.53       24.74       878.32       1         Modelling and Output       6       878.32       7.32       24.945       888.37       1         Equivalent monthly payment       9       8.26.25       6.69       25.57       800.285       77.72       1       1         Total Payments       1,161.62       10       77.72       6.48       25.67       751.48       1       1         Total Payments       1,161.62       10       77.72       6.48       26.79       751.48       1       1         Total Payments       1,161.62       11       77.14       6.26       26.00       72.54       6.69       26.58       77.72       1       1       1.62       1       1       1.646.16       2.22       1.64       6.72.82       2.6       1       1       1.65.72       2.6       6.646.16       2.2       1.646.16       2.2       1.646.16       2.8       6.71.1 <td></td> <td></td> <td>2</td> <td>976.07</td> <td>8.13</td> <td>24.13</td> <td>951.93</td> <td>1</td>			2	976.07	8.13	24.13	951.93	1			
Interest Rate (Annual Percentage Rate)       10%       4       927.00       7.73       24.54       903.06       1         Monthly interest rate       0.83%       6       903.06       7.53       24.74       878.32       1         Modelling and Output       7       863.37       7.11       25.16       828.22       1       828.22       6.60       25.58       777.27       1         Enditional monthly payment       32.27       9       802.82       6.60       25.68       777.27       1         Total Payments       1161.62       10       777.27       6.48       25.67       761.48       1         Total Interest       161.62       11       751.48       6.60       26.22       669.26       1         Key       161.62       11       751.48       6.60       26.22       669.26       1         Iputs       161.62       11       754.86       6.05       26.22       669.26       1       2	Parameter input		3	951.93	7.93	24.33	927.60	1			
Monthlyinterest rate         0.83%         5         903 (6)         7.53         24.74         878.32         1           Modelling and Output         7         863.37         7.31         25.16         683.37         1           Equivalent monthly payment         822.27         9         802.85         6.69         25.57         802.26         1           Itel         32.27         9         802.85         6.69         25.58         7.77.72         1           Total Payments         1,161.62         10         77.72         6.48         26.69         25.68         77.77.7         1           Total Interest         161.62         11         77.54         6.65         26.22         699.26         1           Key         16         67.83         26.44         6.72.82         2         1	Interest Rate (Annual Percentage Rate)	10%	4	927.60	7.73	24.54	903.06	1			
Modelling and Output         Image: Modelling and Output         Image	Monthly interest rate	0.83%	E	903.06	7.53	24.74	878.32	1			
Modelling and Output       v       7       863.37       7.11       25.16       828.22       1         Equivalent monthly payment       32.27       9       802.85       6.69       25.65       777.27       1         Total Payments       1,161.62       10       777.27       6.48       25.79       751.48       11         Total Interest       161.62       11       771.27       6.48       26.60       725.48       11         Rey       161.62       11       771.27       6.48       26.60       725.48       11         Rey       161.62       11       772.48       6.06       26.22       699.26       11         Rey       12       725.48       6.06       26.83       26.44       672.82       22         Interest cols in column       14       672.82       5.61       26.66       646.16       28.20       22       22       12 <t< td=""><td></td><td></td><td>6</td><td>878.32</td><td>7.32</td><td>24.95</td><td>853.37</td><td>1</td></t<>			6	878.32	7.32	24.95	853.37	1			
Equivalent monthly payment         32.27         9         802.82         6.90         25.37         802.86         1           EM         32.27         9         802.86         6.69         25.68         777.27         1           Total Payments         1,161.62         10         777.27         6.48         25.79         751.48         1           Total Payments         161.62         11         776.48         6.26         26.00         725.48         1           Total Payments         161.62         11         776.48         6.05         26.62         2699.26         1           Key         1         161.62         11         699.26         5.83         26.44         672.82         2           Inputs         1         642.16         5.38         26.88         619.27         2           Distinct calc in column         1         1692.17         493         27.33         564.84         2           1,00.00         1,00.00         1         57.28         4.48         27.79         509.49         2           1,00.00         1         57.27         148.36         40.01         282.65         463.21         2           1,00.00 <td>Modelling and Output</td> <td></td> <td></td> <td>853.37</td> <td>7.11</td> <td>25.16</td> <td>828.22</td> <td>1</td>	Modelling and Output			853.37	7.11	25.16	828.22	1			
EMI       32.27       9       802.66       6.69       25.68       777.27       1         Total Payments       1,161.62       10       777.27       6.48       25.79       751.48       1         Total Interest       161.62       11       751.48       6.26       26.00       725.48       6.61       26.02       669.26       11         Key       0       13       699.26       5.68       26.44       672.82       22       1         Inputs       0       14       672.82       6.61       26.66       646.16       2	Equivalent monthly payment		8	8 828.22	6.90	25.37	802.85	1			
Total Payments       1,161.62       10       777.27       6.48       26.79       751.48       11         Total Interest       181.62       11       751.48       6.26       26.00       725.48       1         Key       1       161.62       11       751.48       6.26       26.00       725.48       1         Key       1       1       726.48       6.06       26.22       699.26       1         Inputs       1       699.26       5.83       26.44       672.82       22         Distinct calc in column       1       672.82       5.61       26.66       646.16       22         1,000.0       1       5       646.44       127.11       592.17       22       23       24.47       4.93       27.33       564.84       22       22       18       564.84       4.71       27.56       537.28       22       22       463.21       27       19       537.28       4.48       27.79       509.49       22       23       424.72       24       38.99       32.02       481.46       22       24       33.51       22       24       33.69       22       22       438.99       33.30       28.97       367.0	EMI	32.27	9	802.85	6.69	25.58	777.27	1			
Total Interest       161.62       11       751.48       6.26       26.00       725.48       11         Key       I       12       725.48       6.05       26.22       699.26       11         Inputs       I       161.62       11       725.48       6.05       26.22       699.26       11         Distinct calc in column       I       I       672.82       5.61       26.68       619.27       22         Balance - BoP       I       6161.27       5.16       27.11       592.17       4.93       27.33       564.84       22         1,00.00       I       I       567.88       4.48       27.79       609.49       22         100.00       I       III       18       664.84       4.71       27.56       637.28       22         100.00       I       IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Total Payments	1,161.62	10	777.27	6.48	25.79	751.48	1			
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Total Interest	161.62	11	751.48	6.26	26.00	725.48	1			
Key       In       <			12	725.48	6.05	26.22	699.26	1			
Inputs         Inputs<	Кеу		13	699.26	5.83	26.44	672.82	2			
Distinct calc in column       ind	Inputs		14	672.82	5.61	26.66	646.16	2			
Balance - BoP         Ind         Ind         Gene	Distinct calc in column		18	646.16	5.38	26.88	619.27	2			
Balance - BoP       17       592.17       4.93       27.33       564.84       2         1,200.00       -       -       18       564.84       4.71       22.66       537.28       22         1,000.00       -       -       19       537.28       4.48       27.79       509.49       22         20       509.49       4.25       28.00       481.46       22       433.21       22         21       481.46       4.01       28.25       453.21       22       22       445.25       28.00       481.46       22         600.00       -       -       -       23       424.72       3.54       28.73       395.99       22       23       424.72       3.54       28.73       395.99       22       26       367.02       20       20       26       367.02       3.00       28.97       367.02       22       26       367.02       3.06       29.21       337.81       33       33       26       337.81       2.82       29.94       248.72       33       33       29       248.72       20.07       30.19       218.53       33       33       30       218.53       1.82       30.45       188.08       <			16	619.27	5.16	27.11	592.17	2			
Balance - BOP       18       564.84       4.71       27.56       537.28       2         1,200.00       19       537.28       4.48       27.79       509.49       2         1,000.00       20       509.49       4.25       28.02       481.46       2         20       509.49       4.25       28.02       481.46       2       2         21       481.46       4.01       28.25       481.46       2       2         22       483.21       3.78       28.49       424.72       2       2         23       424.72       3.54       28.73       395.99       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       2       367.02       2       3       3       3       2       2       367.02       2       3       3       3       3       3       3       3       3       3       3       3       3       3       3       3	Delenee		17	592.17	4.93	27.33	564.84	2			
1,200.00       19       537.28       4.48       27.79       509.49       2         1,000.00       20       509.49       4.25       28.02       481.46       2         800.00       22       463.21       28.49       424.72       2         600.00       23       424.72       3.54       28.73       395.99       2         400.00       24       35.99       3.30       28.87       367.02       2         20       507.28       3.30       28.87       367.02       2         400.00       20       337.81       28       337.81       38       3         200.00       20.00       23       367.02       3.06       29.21       337.81       3         200.00       20.00	Balance - I	BOP	18	564.84	4.71	27.56	537.28	2			
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1,200.00			537.28	4.48	27.79	509.49	2			
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			20	509.49	4.25	28.02	481.46	2			
800.00       22       453.21       3.78       28.49       424.72       2         600.00       23       424.72       3.54       28.73       395.99       2         400.00       24       395.99       3.30       28.97       367.02       2         200.00       26       337.81       2.82       29.45       308.36       3         200.00       27       308.36       2.57       29.70       27.867       3         200.00       28       27.867       2.32       2.9.94       248.72       3         200.00       28       27.867       2.32       2.9.94       248.72       3         200.01       28       27.867       2.32       2.9.94       248.72       3         200.02       29       248.72       2.007       30.19       218.53       3         200.02       35       7.9 11 13 15 17 19 21 23 25 27 29 31 33 55       30       218.53       1.82       30.45       188.08       3         30       218.53       1.82       30.45       188.08       3       3       3       3       3       3       3       3       3       3       3       3       3       3	1,000.00		21	481.46	4.01	28.25	453.21	2			
800.00       23       424.72       3.64       28.73       395.99       2         600.00       24       395.99       3.30       28.97       367.02       2         400.00       25       367.02       3.06       29.21       337.81       3         200.00       26       337.81       2.82       29.45       308.36       3         200.00       27       308.36       2.57       29.94       248.72       3         200.00       28       278.67       2.32       29.94       248.72       3         200.00       28       278.67       2.32       29.94       248.72       3         200.00       28       278.67       2.32       29.94       248.72       3         200.00       28       278.67       2.32       29.94       248.72       3         200.01       28       278.67       2.32       29.94       248.72       3         30       218.53       1.82       30.45       188.08       3       3         31       188.08       1.67       30.70       157.38       3       3         31       28       28       27.13       33			22	453.21	3.78	28.49	424.72	2			
600.00       24       395.99       3.30       28.97       367.02       2         400.00       25       367.02       3.06       29.21       337.81       3         200.00       27       308.36       2.57       29.45       308.36       3         200.00       28       27       308.36       2.57       29.70       278.67       3         200.00       28       278.67       2.32       29.94       248.72       3       3         200.00       28       278.67       2.32       29.94       248.72       3       3         200.01       28       278.67       2.32       29.94       248.72       3       3         29       248.72       2.07       30.19       218.53       3<	800.00		23	424.72	3.54	28.73	395.99	2			
400.00       25       367.02       3.06       29.21       337.81       3         400.00       26       337.81       2.82       29.45       308.36       33         200.00       200.00       28       27       308.36       2.57       29.94       248.72       33         200.00       200.00       28       278.67       2.32       29.94       248.72       33         200.00       28       278.67       2.32       2.9.94       248.72       33       33         29       248.72       2.007       30.19       218.53       33	600.00		24	395.99	3.30	28.97	367.02	2			
400.00       200.00	000.00		28	367.02	3.06	29.21	337.81	3			
200.00       200.00	400.00		26	337.81	2.82	29.45	308.36	3			
200.00       200.00       200.00       200.00       28       278.67       2.32       29.94       248.72       33         1       3       5       7       9       11       13       15       17       19       21       23       25       27       29       31       30       218.53       1.82       30.45       188.08       33         1       3       5       7       9       11       13       15       17       19       21       23       25       27       29       31       30       218.53       1.82       30.45       188.08       33         1       3       5       7       9       11       13       15       17       9       21       23       25       27       29       31       31       188.08       1.57       30.70       157.38       33       33       31       188.08       1.57       30.70       157.38       33       33       32       157.38       1.31       30.96       126.42       33       34       95.21       0.79       31.47       63.74       33       35       35       63.74       0.53       31.74       32.00       33       36 </td <td></td> <td></td> <td>27</td> <td>308.36</td> <td>2.57</td> <td>29.70</td> <td>278.67</td> <td>3</td>			27	308.36	2.57	29.70	278.67	3			
29       248.72       2.07       30.19       218.53       3         1       3       5       7       9       11       13       15       17       19       21       23       25       27       29       31       30       218.53       1.82       30.45       188.08       3         1       3       5       7       9       11       13       15       17       19       21       23       25       27       29       31       30       218.53       1.82       30.45       188.08       3         1       3       5       7       9       11       13       15       17       9       12       23       25       27       29       31       30       218.53       1.82       30.45       188.08       3         1       1       3       5       7       9       11       57       30       7       157.38       33       3         1       1       1       1       1       1       1       1       1       1       1       1       3       3       1       1       1       1       3       3       1       1 <td>200.00</td> <td></td> <td>28</td> <td>278.67</td> <td>2.32</td> <td>29.94</td> <td>248.72</td> <td>3</td>	200.00		28	278.67	2.32	29.94	248.72	3			
30       218.53       1.82       30.45       188.08       3         1       3       5       7       9       11       13       15       17       19       21       23       25       7       29       31       31       188.08       1.57       30.70       157.38       3			29	248.72	2.07	30.19	218.53	3			
1       3       5       7       9       11       13       15       17       19       21       23       25       27       29       31       33       35       31       188.08       1.57       30.70       157.38       33         -       -       -       -       -       32       157.38       1.31       30.96       126.42       33         -       -       -       -       -       33       126.42       1.05       31.21       95.21       33         -       -       -       -       -       34       95.21       0.79       31.47       63.74       33         -       -       -       -       35       63.74       0.53       31.74       32.00       3         -       -       -       36       32.00       0.27       32.00       -       3			30	218.53	1.82	30.45	188.08	3			
32         157.38         1.31         30.96         126.42         3           33         126.42         1.05         31.21         95.21         3           4         34         95.21         0.79         31.47         63.74         3           5         63.74         0.53         31.74         32.00         3         3           6         36         32.00         0.27         32.00         -         3	1 3 5 7 9 11 13 15 17	19 21 23 25 27 29	31 33 35 31	188.08	1.57	30.70	157.38	3			
Image: Sector of the system			32	157.38	1.31	30.96	126.42	3			
1         34         95.21         0.79         31.47         63.74         3           1         35         63.74         0.53         31.74         32.00         3           3         36         32.00         0.27         32.00         -         3			33	126.42	1.05	31.21	95.21	3			
1         35         63.74         0.53         31.74         32.00         33           36         32.00         0.27         32.00         -         33			34	95.21	0.79	31.47	63.74	3			
36 32.00 0.27 32.00 - 3			38	63.74	0.53	31.74	32.00	3			
			36	32.00	0.27	32.00	-	3			

## Graphical user interfaces available

#### eg https://www.calculator.net/amortization-calculator.html

#### **Amortization Calculator**





#### Amortization schedule

Annual Schedule Monthly Schedule								
Year	Interest	Principal	Ending Balance					
1	\$86.46	\$300.74	\$699.26					
2	\$54.97	\$332.23	\$367.02					
3	\$20.18	\$367.02	\$-0.00					



by Calculator.net

## How to calculate the Equivalent Monthly Installment (EMI)

$$EMI = rac{(1+i)^n}{(1+i)^n - 1} imes i imes L$$

For the derivation and an intuitive understanding see https://math.stackexchange.com/questions/279844/how-theformula-for-emi-is-derived

## Calculating EMI in Excel and R is similar

C13	3 -	: × ✓ fx = (1 + C9)^C5 / ((1	+ C9)^C5 -	1) * C9 *	СЗ				
<i></i>	nternal 🖍								
	А	В	С	D					
1									
2		Data input			Mo				
3		Loan Amount	1,000		Mo				
4		Loan Term (in years)	3		Tim				
5		Loan Term (in months)	36						
6									
7		Parameter input							
8		Interest Rate (Annual Percentage Rate)	10%						
9		Monthly interest rate	0.83%						
10									
11		Modelling and Output							
12		Equivalent monthly payment							
13		EMI	32.27						
14		Total Payments	1,161.62						
15		Total Interest	161.62						
16									
17		Key							
18		Inputs							
19		Distinct calc in column							
20									

```
1 # Data and parameter input
2 A <- 1000
3 n_yr <- 3
4 int_yr <- 0.1
5
6 # Intermediate calculation
7 n <- n_yr * 12
8 i <- int_yr / 12
9
10 emi <- (1 + i)^n / ((1 + i)^n - 1) * i * A
11 emi
```

[1] 32.26719

SU	• N	: × ✓ f <sub>x</sub> =F5+G5-C\$13								
<i>(</i> )	Internal 🖌									
	Α	В	С	D	E	F	G	Н	1	J
1										
2		Data input			Modelling and out	tput				
3		Loan Amount	1,000		Monthly cashflow	/S				
4		Loan Term (in years)	3		Time-months	Balance - BoP	Interest	Principal	Balance - EoP	Time-years
5		Loan Term (in months)	36		1	1,000.00	8.33	23.93	=F5+G5-C\$13	1
6					2	976.07	8.13	24.13	951.93	1
7		Parameter input			3	951.93	7.93	24.33	927.60	1
8		Interest Rate (Annual Percentage Rate)	10%		4	927.60	7.73	24.54	903.06	1
9		Monthly interest rate	0.83%		5	903.06	7.53	24.74	878.32	1
10					6	878.32	7.32	24.95	853.37	1
11		Modelling and Output			7	853.37	7.11	25.16	828.22	1
12		Equivalent monthly payment			8	828.22	6.90	25.37	802.85	1
13		EMI	32.27		9	802.85	6.69	25.58	777.27	1
14		Total Payments	1,161.62		10	777.27	6.48	25.79	751.48	1
15		Total Interest	161.62		11	751.48	6.26	26.00	725.48	1
16					12	725.48	6.05	26.22	699.26	1
17		Key			13	699.26	5.83	26.44	672.82	2
18		Inputs			14	672.82	5.61	26.66	646.16	2
19		Distinct calc in column			15	646.16	5.38	26.88	619.27	2
20					16	619.27	5.16	27.11	592.17	2

SUN	л <b>т</b>	: × ✓ f <sub>x</sub> =F5+F5*C\$9-C\$13									
<i>(</i> ) I	nternal 💉										
	Α	В	С	D	E	F	G	Н	I. I.	J	
1											
2		Data input			Modelling and out	tput					
3		Loan Amount	1,000		Monthly cashflow	/s					
4		Loan Term (in years)	3		Time-months	Balance - BoP	Interest	Principal	Balance - EoP	Time-years	
5		Loan Term (in months)	36		1	1,000.00	8.33	23.93	=F5+F5*C\$9-C\$1	3 I	
6					2	976.07	8.13	24.13	951.93		1
7		Parameter input			3	951.93	7.93	24.33	927.60		1
8		Interest Rate (Annual Percentage Rate)	10%		4	927.60	7.73	24.54	903.06		1
9		Monthly interest rate	0.83%		5	903.06	7.53	24.74	878.32		1
10					6	878.32	7.32	24.95	853.37		1
11		Modelling and Output			7	853.37	7.11	25.16	828.22		1
12		Equivalent monthly payment			8	828.22	6.90	25.37	802.85		1
13		EMI	32.27		9	802.85	6.69	25.58	777.27		1
14		Total Payments	1,161.62		10	777.27	6.48	25.79	751.48		1
15		Total Interest	161.62		11	751.48	6.26	26.00	725.48		1
16					12	725.48	6.05	26.22	699.26		1
17		Кеу			13	699.26	5.83	26.44	672.82		2
18		Inputs			14	672.82	5.61	26.66	646.16		2
19		Distinct calc in column			15	646.16	5.38	26.88	619.27		2
20					16	619.27	5.16	27.11	592.17		2

SU	• M	: × ✓ f <sub>x</sub> =15								
<i></i>	Internal 🖌									
	Α	В	С	D	E	F	G	Н	1	J
1										
2		Data input			Modelling and out	tput				
3		Loan Amount	1,000		Monthly cashflow	/S				
4		Loan Term (in years)	3		Time-months	Balance - BoP	Interest	Principal	Balance - EoP	Time-years
5		Loan Term (in months)	36		1	1,000.00	8.33	23.93	976.07	1
6					2	=15	8.13	24.13	951.93	1
7		Parameter input			3	951.93	7.93	24.33	927.60	1
8		Interest Rate (Annual Percentage Rate)	10%		4	927.60	7.73	24.54	903.06	1
9		Monthly interest rate	0.83%		5	903.06	7.53	24.74	878.32	1
10					6	878.32	7.32	24.95	853.37	1
11		Modelling and Output			7	853.37	7.11	25.16	828.22	1
12		Equivalent monthly payment			8	828.22	6.90	25.37	802.85	1
13		EMI	32.27		9	802.85	6.69	25.58	777.27	1
14		Total Payments	1,161.62		10	777.27	6.48	25.79	751.48	1
15		Total Interest	161.62		11	751.48	6.26	26.00	725.48	1
16					12	725.48	6.05	26.22	699.26	1
17		Кеу			13	699.26	5.83	26.44	672.82	2
18		Inputs			14	672.82	5.61	26.66	646.16	2
19		Distinct calc in column			15	646.16	5.38	26.88	619.27	2
20					16	619.27	5.16	27.11	592.17	2

	В	С	D	E	F	1
1						
2	Data input			Modelling and output		
3	Loan Amount	1000		Monthly cashflows		
4	Loan Term (in years)	3		Time-months	Balance - BoP	Balance - EoP
5	Loan Term (in months)	=C4*12		1	=C3	=F5+F5*C\$9-C\$13
6				=E5+1	=15	=F6+F6*C\$9-C\$13
7	Parameter input			=E6+1	=16	=F7+F7*C\$9-C\$13
8	Interest Rate (Annual Percentage Rate)	0.1		=E7+1	=17	=F8+F8*C\$9-C\$13
9	Monthly interest rate	=C8/12		=E8+1	=18	=F9+F9*C\$9-C\$13
10				=E9+1	=19	=F10+F10*C\$9-C\$13
11	Modelling and Output			=E10+1	=110	=F11+F11*C\$9-C\$13
12	Equivalent monthly payment			=E11+1	= 11	=F12+F12*C\$9-C\$13
13	EMI	= (1 + C9)^C5 / ((1 + C9)^C5 - 1) * C9 * C3		=E12+1	=112	=F13+F13*C\$9-C\$13
14	Total Payments	=C13*C5		=E13+1	=113	=F14+F14*C\$9-C\$13
15	Total Interest	=SUM(G5:G148)		=E14+1	=114	=F15+F15*C\$9-C\$13
16				=E15+1	=115	=F16+F16*C\$9-C\$13
17	Кеу			=E16+1	=116	=F17+F17*C\$9-C\$13
18	Inputs			=E17+1	=117	=F18+F18*C\$9-C\$13
19	Distinct calc in column			=E18+1	=118	=F19+F19*C\$9-C\$13
20				=E19+1	=119	=F20+F20*C\$9-C\$13
21				=E20+1	=120	=F21+F21*C\$9-C\$13
22				=E21+1	=121	=F22+F22*C\$9-C\$13
23				=E22+1	=122	=F23+F23*C\$9-C\$13
24				=E23+1	=123	=F24+F24*C\$9-C\$13

#### $P_{n+1} = P_n + P_n \times i_n - EMI$

## **Vectorisation in R**

#### R supports vectorised calculations. An example:

1 # I have 2 vectors of values 2 x <- c(1, 3, 5, 7) 3 y <- c(2, 4, 6, 8) 4 x
[1] 1 3 5 7

```
l y
```

[1] 2 4 6 8

```
1 # I want to add them together
2 # Because `+` is a vectorised operator, I can do:
3 z <- x + y
4 z</pre>
```

[1] 3 7 11 15

-> No need to copy-paste or drag-down; it appears once

## It is not always easy to vectorise

Eg if subsequent values of a vector depend on the previous value of the same vector.

Writing an explicit iterative loop is a often a solution. The previous example:

```
1 z <- double(length = length(x))  # initialise output
2 for (j in 1:length(z)) {  # iterator
3 z[j] <- x[j] + y[j]  # body of loop
4 }
5 z
```

```
[1] 3 7 11 15
```

#### It works but often verbose

## **Recursion may help**

Recursion can potentially succinctly describe the calculation

- We will explore a couple of functions that can help: reduce() and accumulate()
- But we will start with sum() and cumsum() which can be considered special cases of the above

## +, Sum, Cumsum

## + and sum

+ is a binary operator for addition, under the hood is a function

1	1 + 2
[1]	3
1	`+`(1, 2)
[1]	3

#### Can't use more than 2 arguments (binary operator)

1 `+`(1, 2, 3)

Error in `+`(1, 2, 3): operator needs one or two arguments

#### Can apply + iteratively, thankfully we have: sum

1	`+`(3, `+`(1, 2))	# inconvenient
[1]	6	
1	sum(1, 2, 3)	
[1]	6	

### + and cumsum

```
1 x <- c(1, 2, 3)
2 x
```

[1] 1 2 3

#### Calculate cumulative sum

1 c(x[1], x[1] + x[2], x[1] + x[2] + x[3])

[1] 1 3 6

#### Thankfully we have cumsum as a function

1 cumsum(x)

[1] 1 3 6

#### base::Reduce

Reduce uses a binary function to successively combine the elements of a given vector

Define a vector

```
1 x <- c(1, 2, 3)
2 x
```

[1] 1 2 3

#### Successively combine elements of x using a binary function

1 Reduce (f = +, x = x)

# with + it is like sum

[1] 6

#### Accumulate the successive reduce combinations

1 Reduce(f = +, x = x, accumulate = TRUE) # with + it is like cumsum

[1] 1 3 6

#### purrr::reduce and accumulate

```
1 \times < - c(1, 2, 3)
```

```
2 purrr::reduce(.x = x, .f = +)
```

[1] 6

```
1 purrr::accumulate(.x = x, .f = `+`)
```

[1] 1 3 6

Compared to base R, purr functions consistently use . as a prefix, are type stable, and all start with the data, followed by the function

## accumulate exercise 1

#### Start with a vector of values

```
1 x <- c(2, 3, 5)
2 x
```

[1] 2 3 5

#### Define a 2-argument function

1 fn <- function(a, b)  $\{a^2 + b\}$ 

#### Apply the function successively over the elements of x

```
1 # first argument: result of previous application
```

```
2\ \mbox{\#} second argument: the next value of the vector
```

```
3 purrr::accumulate(.x = x, .f = fn)
```

```
[1] 2 7 54
```

#### accumulate exercise 2

- Apply a 1-argument function to a single value for k times
- Use accumulate() by neutralising the 2nd argument value



## Amortise

#### Using values of the first example:



	D	E	F
1			
2		Modelling and	output
3		Monthly cashf	lows
4		Time-months	Balance - BoP
5		1	1,000.00
6		2	976.07
7		3	951.93
8		4	927.60
9		5	903.06
10		6	878.32
11		7	853.37
12		8	828.22

we define: 
$$P_{n+1} = P_n + P_n imes i_n - EMI$$

1 fn3 <- function(a, b) {a + a \* i - emi}

#### And apply it

```
1 P <- purrr::accumulate(1:(n-1), fn3, .init = A)
2 P[1:8]
[1] 1000.0000 976.0661 951.9328 927.5984 903.0612
878.3196 853.3717</pre>
```

[8] 828.2159

## Putting it all together for one value

[1] 1000.0000 976.0661 951.9328 927.5984 903.0612 878.3196

Many working patterns are common between Excel and R. It often pays off to switch mindset from spreadsheet computing to programming (will see examples next week)

# Next: From programming in R to putting R into production

Building on current example:

- Build functions to reuse logic and abstract away complexity
- Iterate over all data with functional programming approach
- Bundle functions into packages (programmer-toprogrammer interface)
- Expose functions into Shiny (graphical user interface)
- Expose functions into Web APIs (computer-to-computer interface)

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## R consortium

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