Passage 24 A #7

In this course, we have learnt,

1) An overview of the world population in the past.
2) Simple population dynamics model as exponential growth.
3) Other models in which annual growth decreases or increases with time.
4) Age structured population dynamimcs model using vector and matrix.
5) Estimate of maximum world population with various limiting factors.

Today, we work on the following problem.

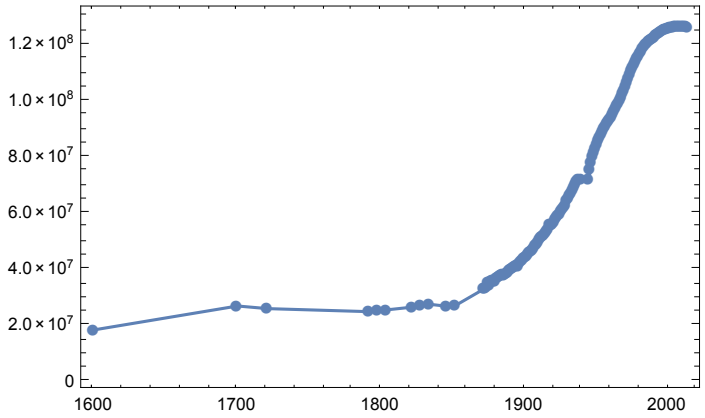
Problem

1) Pick up a country you like and describe the country' s demographic change in the past for available data.
2) Calculate annual growth rates for each year and examine its trend (increasing or decreasing?).
3) Predict the country population size under the assumption that the present trend continues in the future.

Example Japan

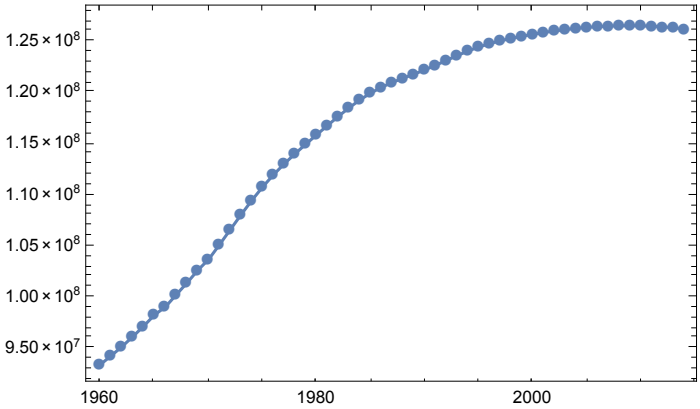
Let' s choose Japan and draw its demographic change for all available data.

```
DateListPlot[CountryData["Japan", {"Population", All}], PlotMarkers → Automatic]
```



We focus on a narrower time span from 1960 to 2014.

```
DateListPlot[CountryData["Japan", {"Population", {1960, 2014}}],
 PlotMarkers → Automatic]
```



From the demogrpahic data, we calculate annual growrh rate for each year.

```
dataCountry = CountryData["Japan", {"Population", {1960, 2014}}]
```

```
TimeSeries[ Time: 01 Jan 1960 to 01 Jan 2014
            Data points: 55 ]
```

We can pick up the pouplation size from the data.

```
dataCountry["1990"]
```

```
122 251 184 people
```

```
dataCountry["2014"]
```

```
126 225 259 people
```

```
tableYears = Table[TextString[t], {t, 1960, 2014}]
```

```
{1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973,
 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987,
 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001,
 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014}
```

List the population sizes from 1960 to 2014 (there are 55 data).

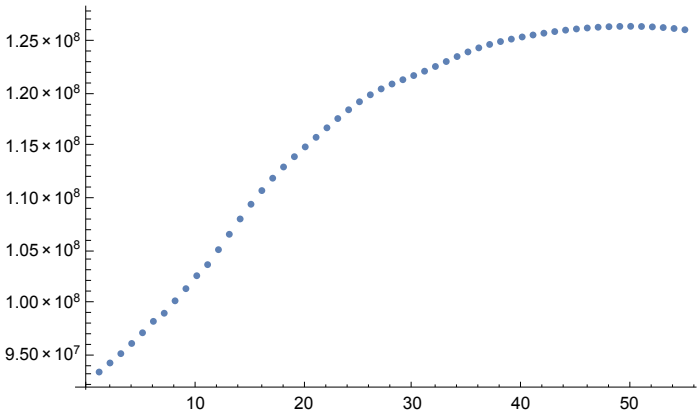
```
dataCountryPopSize = dataCountry[tableYears]
Length[dataCountryPopSize]
```

```
{93 418 500 people, 94 287 000 people, 95 181 000 people,
 96 156 000 people, 97 182 000 people, 98 275 000 people, 99 054 000 people,
 100 243 000 people, 101 408 000 people, 102 648 000 people, 103 710 287 people,
 105 145 914 people, 106 619 818 people, 108 089 192 people, 109 498 615 people,
 110 808 090 people, 111 996 339 people, 113 071 149 people, 114 057 650 people,
 114 996 088 people, 115 914 688 people, 116 823 958 people, 117 711 145 people,
 118 554 190 people, 119 320 901 people, 119 990 547 people, 120 553 260 people,
 121 023 579 people, 121 434 677 people, 121 832 924 people, 122 251 184 people,
 122 703 017 people, 123 177 552 people, 123 653 405 people, 124 097 649 people,
 124 486 744 people, 124 814 986 people, 125 091 571 people, 125 325 617 people,
 125 531 619 people, 125 720 310 people, 125 893 623 people, 126 048 366 people,
 126 184 149 people, 126 299 414 people, 126 392 944 people, 126 464 789 people,
 126 515 486 people, 126 544 640 people, 126 551 705 people, 126 535 920 people,
 126 497 241 people, 126 434 653 people, 126 345 235 people, 126 225 259 people}
```

```
55
```

And visualize the list of the population sizes from 1960.

```
gPast = ListPlot[dataCountryPopSize]
```



We calcualte annual growth rate for each year.

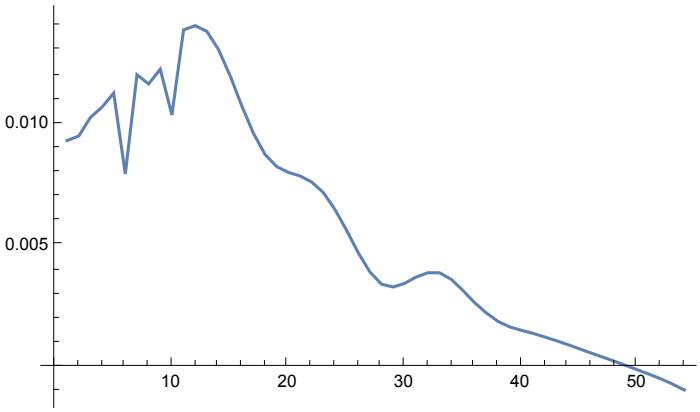
```
dataAnnualGrowthRate = {};
Do[
 AppendTo[dataAnnualGrowthRate,
  N[(dataCountryPopSize[[i + 1]] - dataCountryPopSize[[i]]) /
    dataCountryPopSize[[i]]]], {i, 1, Length[dataCountryPopSize] - 1}
]
```

```
dataAnnualGrowthRate
```

```
{0.00929687, 0.00948169, 0.0102436, 0.0106702, 0.0112469, 0.00792674, 0.0120036,
 0.0116218, 0.0122278, 0.0103488, 0.0138427, 0.0140177, 0.0137814, 0.0130394,
 0.0119588, 0.0107235, 0.00959683, 0.0087246, 0.00822775, 0.0079881,
 0.0078443, 0.00759422, 0.00716198, 0.00646718, 0.00561214, 0.00468964,
 0.00390134, 0.00339684, 0.00327952, 0.00343306, 0.00369594, 0.00386735,
 0.00386315, 0.00359265, 0.00313539, 0.00263676, 0.00221596, 0.001871,
 0.00164373, 0.00150314, 0.00137856, 0.00122916, 0.00107723, 0.000913467,
 0.000740542, 0.000568426, 0.000400878, 0.000230438, 0.0000558301,
 -0.000124732, -0.000305676, -0.000494778, -0.000707227, -0.000949589}
```

Visualize the annual growth rate from 1960 to 2014 (The year 1960 is 1st year in the graph).

```
ListPlot[dataAnnualGrowthRate, Joined → True, PlotRange → All]
```



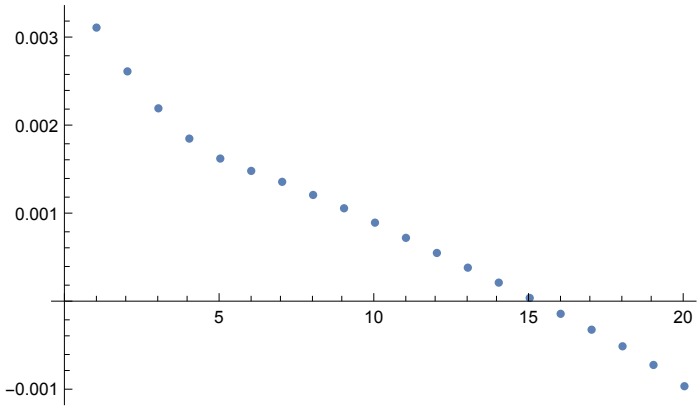
We focus on the recent 20 years to calcualte the trend of the annual growth rate change.

```
dataLast = Take[dataAnnualGrowthRate, -20]
```

```
{0.00313539, 0.00263676, 0.00221596, 0.001871, 0.00164373,
 0.00150314, 0.00137856, 0.00122916, 0.00107723, 0.000913467,
 0.000740542, 0.000568426, 0.000400878, 0.000230438, 0.0000558301,
 -0.000124732, -0.000305676, -0.000494778, -0.000707227, -0.000949589}
```

Visualize the recent annual growth rate.

```
gDataAnnualGrowthRate = ListPlot[dataLast]
```



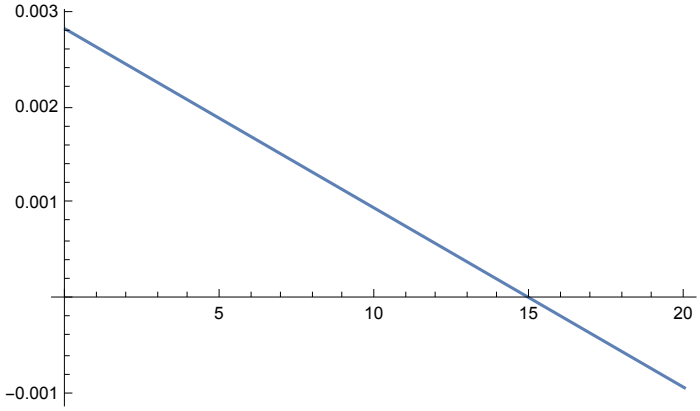
We fit the data with a linear function (straight line) of the year t.

```
fitted = Fit[dataLast, {1, t}, t]
```

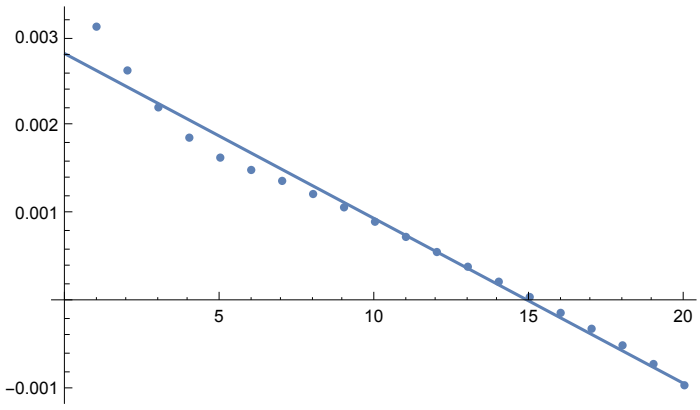
```
0.00282285 - 0.000187802 t
```

The annual growth rate decreases by 0.000187802 every year.

```
gFitted = Plot[fitted, {t, 0, 20}]
```




```
Show[gDataAnnualGrowthRate, gFitted]
```



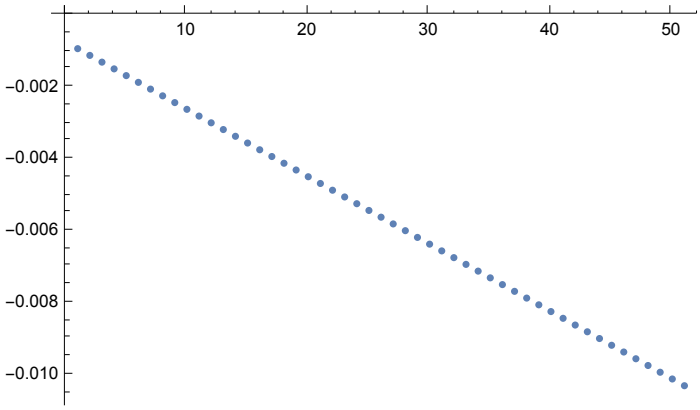
We calculate the predicted annual growth rate for 50 years in future based on the trend.

```
tPeriod = 50;
seqGrowthRate = Table[fitted, {t, 20, 20 + tPeriod}]
```

```
{-0.000933194, -0.001121, -0.0013088, -0.0014966, -0.0016844, -0.0018722,
 -0.00206001, -0.00224781, -0.00243561, -0.00262341, -0.00281121, -0.00299902,
 -0.00318682, -0.00337462, -0.00356242, -0.00375023, -0.00393803, -0.00412583,
 -0.00431363, -0.00450143, -0.00468924, -0.00487704, -0.00506484, -0.00525264,
 -0.00544044, -0.00562825, -0.00581605, -0.00600385, -0.00619165, -0.00637945,
 -0.00656726, -0.00675506, -0.00694286, -0.00713066, -0.00731846,
 -0.00750627, -0.00769407, -0.00788187, -0.00806967, -0.00825748,
 -0.00844528, -0.00863308, -0.00882088, -0.00900868, -0.00919649,
 -0.00938429, -0.00957209, -0.00975989, -0.00994769, -0.0101355, -0.0103233}
```

Visuzlize the predicted annual growth rate.

```
ListPlot[seqGrowthRate]
```



We calculate the population size in the future starting from the size at the year 2014.

```
dataCountry["2014"]
```

```
126 225 259 people
```

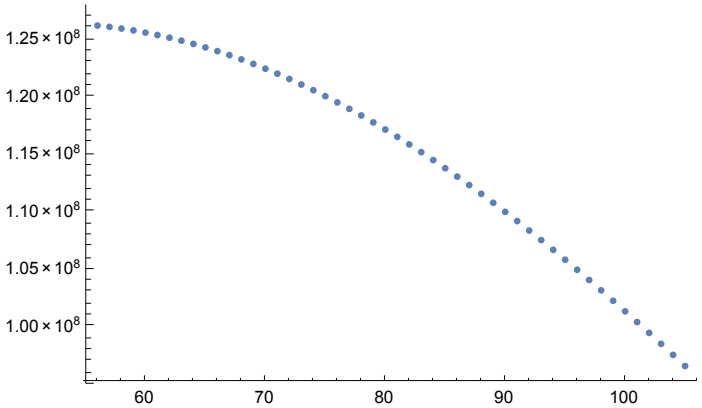
```
data = {};
popSize = 126 225 259 people ;

Do[
 AppendTo[data, popSize];
 popSize = popSize * (1 + seqGrowthRate[[i]]);, {i, 1, tPeriod}
]
```

```
dataPredicted = Transpose[{Table[t, {t, 56, 56 + tPeriod - 1}], data}]
```

$$\{\{56,\ 126\,225\,259\ \text{people}\},\ \{57,\ 1.26107\times10^{8}\ \text{people}\},$$
$$\{58,\ 1.25966\times10^{8}\ \text{people}\},\ \{59,\ 1.25801\times10^{8}\ \text{people}\},\ \{60,\ 1.25613\times10^{8}\ \text{people}\},$$
$$\{61,\ 1.25401\times10^{8}\ \text{people}\},\ \{62,\ 1.25167\times10^{8}\ \text{people}\},\ \{63,\ 1.24909\times10^{8}\ \text{people}\},$$
$$\{64,\ 1.24628\times10^{8}\ \text{people}\},\ \{65,\ 1.24324\times10^{8}\ \text{people}\},\ \{66,\ 1.23998\times10^{8}\ \text{people}\},$$
$$\{67,\ 1.2365\times10^{8}\ \text{people}\},\ \{68,\ 1.23279\times10^{8}\ \text{people}\},\ \{69,\ 1.22886\times10^{8}\ \text{people}\},$$
$$\{70,\ 1.22471\times10^{8}\ \text{people}\},\ \{71,\ 1.22035\times10^{8}\ \text{people}\},\ \{72,\ 1.21577\times10^{8}\ \text{people}\},$$
$$\{73,\ 1.21099\times10^{8}\ \text{people}\},\ \{74,\ 1.20599\times10^{8}\ \text{people}\},\ \{75,\ 1.20079\times10^{8}\ \text{people}\},$$
$$\{76,\ 1.19538\times10^{8}\ \text{people}\},\ \{77,\ 1.18978\times10^{8}\ \text{people}\},\ \{78,\ 1.18397\times10^{8}\ \text{people}\},$$
$$\{79,\ 1.17798\times10^{8}\ \text{people}\},\ \{80,\ 1.17179\times10^{8}\ \text{people}\},\ \{81,\ 1.16541\times10^{8}\ \text{people}\},$$
$$\{82,\ 1.15886\times10^{8}\ \text{people}\},\ \{83,\ 1.15212\times10^{8}\ \text{people}\},\ \{84,\ 1.1452\times10^{8}\ \text{people}\},$$
$$\{85,\ 1.13811\times10^{8}\ \text{people}\},\ \{86,\ 1.13085\times10^{8}\ \text{people}\},\ \{87,\ 1.12342\times10^{8}\ \text{people}\},$$
$$\{88,\ 1.11583\times10^{8}\ \text{people}\},\ \{89,\ 1.10808\times10^{8}\ \text{people}\},\ \{90,\ 1.10018\times10^{8}\ \text{people}\},$$
$$\{91,\ 1.09213\times10^{8}\ \text{people}\},\ \{92,\ 1.08393\times10^{8}\ \text{people}\},\ \{93,\ 1.07559\times10^{8}\ \text{people}\},$$
$$\{94,\ 1.06712\times10^{8}\ \text{people}\},\ \{95,\ 1.05851\times10^{8}\ \text{people}\},\ \{96,\ 1.04976\times10^{8}\ \text{people}\},$$
$$\{97,\ 1.0409\times10^{8}\ \text{people}\},\ \{98,\ 1.03191\times10^{8}\ \text{people}\},\ \{99,\ 1.02281\times10^{8}\ \text{people}\},$$
$$\{100,\ 1.0136\times10^{8}\ \text{people}\},\ \{101,\ 1.00427\times10^{8}\ \text{people}\},$$
$$\{102,\ 9.9485\times10^{7}\ \text{people}\},\ \{103,\ 9.85328\times10^{7}\ \text{people}\},$$
$$\{104,\ 9.75711\times10^{7}\ \text{people}\},\ \{105,\ 9.66005\times10^{7}\ \text{people}\}\}$$

Visualize the predicted demography.

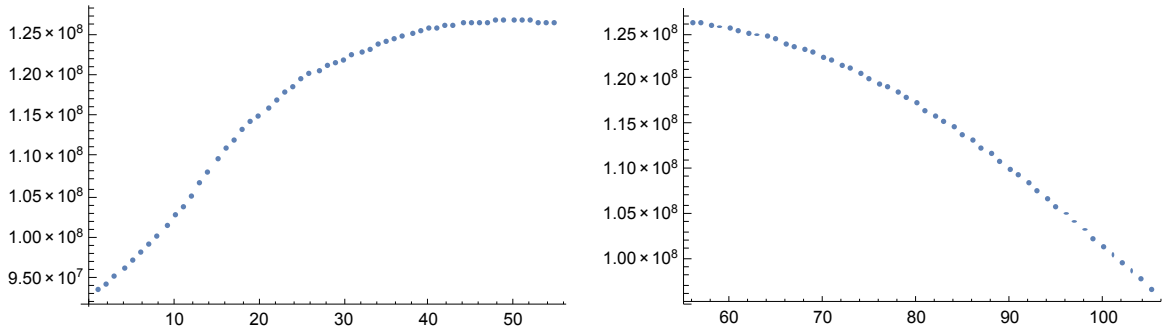
```
gPredicted = ListPlot[dataPredicted]
```



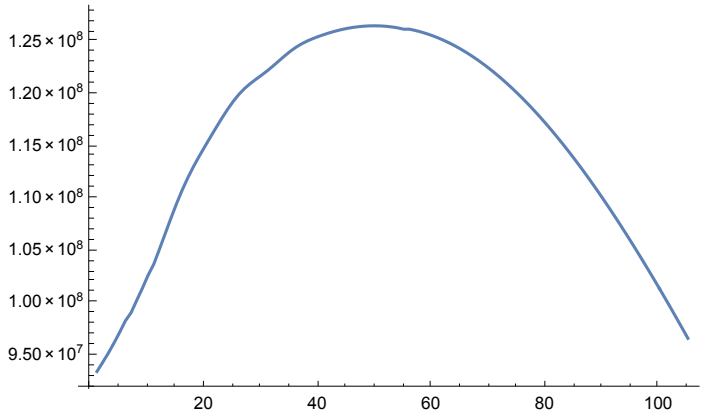
```
dataPast =
 Transpose[{Table[t, {t, 1, Length[dataCountryPopSize]}], dataCountryPopSize}]
```

```
{{1, 93 418 500 people}, {2, 94 287 000 people},
 {3, 95 181 000 people}, {4, 96 156 000 people}, {5, 97 182 000 people},
 {6, 98 275 000 people}, {7, 99 054 000 people}, {8, 100 243 000 people},
 {9, 101 408 000 people}, {10, 102 648 000 people}, {11, 103 710 287 people},
 {12, 105 145 914 people}, {13, 106 619 818 people},
 {14, 108 089 192 people}, {15, 109 498 615 people}, {16, 110 808 090 people},
 {17, 111 996 339 people}, {18, 113 071 149 people}, {19, 114 057 650 people},
 {20, 114 996 088 people}, {21, 115 914 688 people}, {22, 116 823 958 people},
 {23, 117 711 145 people}, {24, 118 554 190 people}, {25, 119 320 901 people},
 {26, 119 990 547 people}, {27, 120 553 260 people}, {28, 121 023 579 people},
 {29, 121 434 677 people}, {30, 121 832 924 people}, {31, 122 251 184 people},
 {32, 122 703 017 people}, {33, 123 177 552 people}, {34, 123 653 405 people},
 {35, 124 097 649 people}, {36, 124 486 744 people}, {37, 124 814 986 people},
 {38, 125 091 571 people}, {39, 125 325 617 people}, {40, 125 531 619 people},
 {41, 125 720 310 people}, {42, 125 893 623 people}, {43, 126 048 366 people},
 {44, 126 184 149 people}, {45, 126 299 414 people}, {46, 126 392 944 people},
 {47, 126 464 789 people}, {48, 126 515 486 people}, {49, 126 544 640 people},
 {50, 126 551 705 people}, {51, 126 535 920 people}, {52, 126 497 241 people},
 {53, 126 434 653 people}, {54, 126 345 235 people}, {55, 126 225 259 people}}
```

```
GraphicsGrid[{{gPast, gPredicted}}, ImageSize → 600]
```



```
dataJoined = Join[dataPast, dataPredicted];
ListPlot[dataJoined, Joined → True]
```



Example Germany

Example The World