Simulating a doctor's waiting room

Goal: Simulate the queuing behavior at a doctor's office.

Assumptions:

1 Patients arrive on the minutes between 9:00 am and 11:59 am.

2 At most one patient arrives during any minute.

3 The probability that a patient arrives in any one minute is 0.075.

4 Each patient needs to meet with the doctor for 15 minutes.

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Expectations:

1 How many patients does the doctor expect to see in the day?

2 How much time does the doctor expect to spend with patients?

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How do we simulate the arrival of patients?

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$i = \underline{\hphantom{000}}$ occurs at time 11:59 am.

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$$i = \underline{\quad} \text{ occurs at time 11:59 am.}$$

We set up a For loop:

```
For[i = 0, i _____, i _____,
   newPatient = If[RandomReal[] <= 0.075, 1, 0] ]
```

Dealing with the waiting

How do we simulate "waiting" in a "waiting room"?

An arriving patient will wait when _____.

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An arriving patient will wait when _____.

We will keep track of the following variables:

$$\texttt{nwait} = \text{The number of patients waiting.}$$

$$\texttt{endTime} = \begin{array}{l}\text{The time when the current patient} \\ \text{finishes with the doctor.}\end{array}$$

$$\texttt{busy} = \left\{ \begin{array}{l} 1 \text{ if the doctor is busy} \\ 0 \text{ if the doctor is free} \end{array} \right\}$$

Simulating a doctor's waiting room

Now translate the flowchart into an algorithm:

Pseudocode:

▶ Zero out the counters.

▶ For `i` from 0 up to 180,

    ▶ If the doctor is finishing with a patient at time `i`, then set busy=0.

    ▶ Determine if a new patient arrives (random, probability 0.075).
    If so, set `newPatient` to 1; otherwise set `newPatient` to 0.

    ▶ If `newPatient == 1`, add one to the number waiting (`nwait++`)

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▶ For i from 0 up to 180,

   ▶ If the doctor is finishing with a patient at time i, then set busy=0.
   ▶ Determine if a new patient arrives (random, probability 0.075).
     If so, set newPatient to 1; otherwise set newPatient to 0.
   ▶ If newPatient == 1, add one to the number waiting (nwait++)
   ▶ If the doctor is not busy AND there is a patient waiting,

      ▶ Subtract one from the number waiting (nwait--)
      ▶ Set the doctor to be busy (busy = 1)
      ▶ Set the time when the doctor is not busy (endTime = i + 15).

Dealing with the waiting

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
   ]
```

▶ For i from 0 up to 180,
  ▶ If the doctor is finishing with a patient at time i, then set busy=0.
  ▶ Determine if a new patient arrives (random, probability 0.075).
    If so, set newPatient to 1; otherwise set newPatient to 0.
  ▶ If newPatient == 1, add one to the number waiting (nwait++)
  ▶ If the doctor is not busy AND there is a patient waiting,
    ▶ Subtract one from the number waiting (nwait--)
    ▶ Set the doctor to be busy (busy = 1)
    ▶ Set the time when the doctor is not busy to $i + 15$.

What does the simulation tell us?

We did the simulation, but what was the point?

▶ How much of the day will the doctor will be busy?
▶ What is the average number of patients in the waiting room?
▶ How many people are in the waiting room at noon?
▶ How late will the doctor stay after noon?

What does the simulation tell us?

We did the simulation, but what was the point?

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- ▶ What is the average number of patients in the waiting room?
- ▶ How many people are in the waiting room at noon?
- ▶ How late will the doctor stay after noon?

What statistics do we need to keep track of to answer these questions?
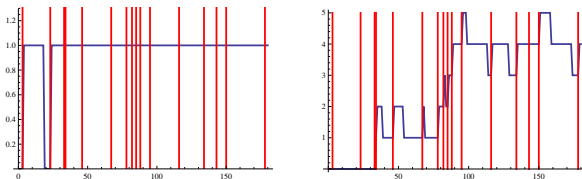
This is just one instance; the power of simulation comes from running the model many times and understanding the average behavior.

Gathering data

▶ How many people are in the waiting room at noon?

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
    If[endTime == i, busy = 0];
    newPatient = If[RandomReal[] <= 0.075, 1, 0];
    If[newPatient == 1, nwait++];
    If[busy == 0 && nwait > 0,
        nwait--; busy = 1; endTime = i + 15];
    ];
nwait ⟵ [Outputs the value after the loop ends.]
```
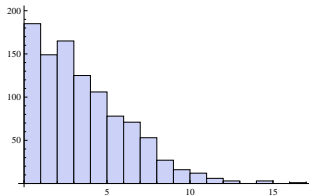
Running many trials

▶ How many people are in the waiting room at noon?

Simulate 1000 times using a `Table` command, generate a histogram.

```
trials = Table[
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
   ];
nwait  ], {j,1000}]
Mean[trials]  ⟵ [Average: 3.105]
Histogram[trials]
```
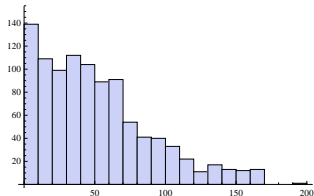
Gathering data

▶ How late will the doctor stay after noon?

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
   ];
*****
```

↑ [*How to calculate how long
the doctor has to stay after noon?*]

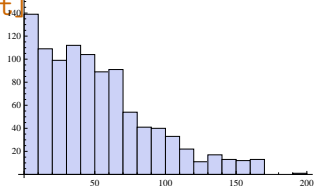Mean: 51 minutes (does this make sense?)

Gathering data

▶ How late will the doctor stay after noon?

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
   ];
If[busy == 0, 0, endTime + 15 * nwait]
```

↑ [*How to calculate how long
the doctor has to stay after noon?*]

Mean: 51 minutes (does this make sense?)

Gathering and plotting time-dependent data

▶ How much of the day will the doctor will be busy?

Keep track of if the doctor is busy by using a variable `isBusy`.

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
   isBusy[i]=busy;  ⟵ [this copies busy into isBusy[i].]
   ];          ↓ [Puts data into a list.]
busyList=Table[isBusy[i],i,0,179]
Total[busyList]  ⟵ [Total time busy.]
ListLinePlot[busyList]
```
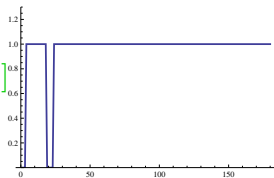
Gathering and plotting time-dependent data

▶ What is the average number of patients in the waiting room?

Keep track of number of waiting patients by using a variable `numWait`.

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
   numWait[i]=nwait; ⟵ [this copies nwait into numWait[i].]
   ];           ↓ [Puts data into a list.]
waitList=Table[numWait[i],i,0,179]
m=Mean[waitList] ⟵ [Average patients.]
p1=ListLinePlot[waitList];
p2=Plot[m,x,0,179];
Show[p1,p2]
```