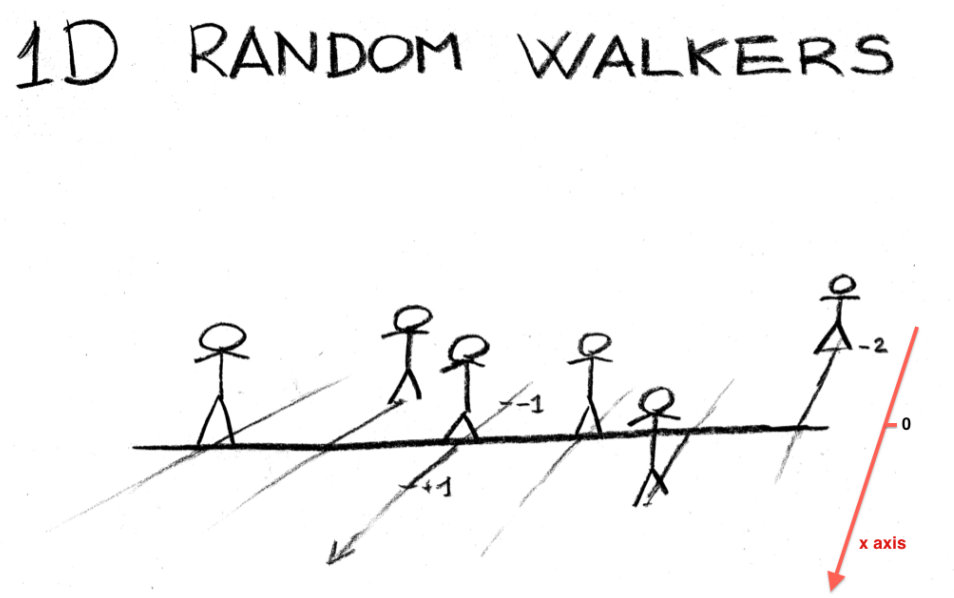

FIG. 1: An ensemble of human random walkers in one-dimension.

Outside-class Activity: 1D Zen random walkers

October 21st, 2013, 11.35am
Becton Plaza

Today we will perform an *experiment*, a human experiment since you, yourselves are going to be the data that we want to analyze and then compare with a *theory*. We will realize an ensemble of human random walkers in one-dimension and then compare our findings with the prediction from the Binomial Distribution. You will learn why and how experiments might not agree with the theory sometimes, furthermore the activity should be useful to trigger your intuition about how a *diffusive process* behaves in time and space.

LEARNING GOALS

- learn how to generate a random walk in time from a set of random variables (coin flips)
- identify how a random walk can be described by a Binomial Distribution
- learn that experiments may disagree with the theoretical predictions and why
- estimate what the *mean* and *standard deviation* are for a random walk
- understand how the *variance* and *standard deviation* of a random walk depend on time
- equivalently, appreciate how a random walk *diffuses* in space.

PUT YOURSELF IN THE 1D RANDOM WALKER'S SHOES

On Monday, October 21st, **11.35am** (please be on time!) we will all meet in **Becton Plaza** (an open outside space just behind the Becton Center, 15 Prospect Street, you can also access it from Hillhouse Street, there is a pedestrian path just across from the TEAL classroom) and we will realize an *ensemble* of 1D random walks. An ensemble is a set or collection of many similar systems, in our case the system is a 1D random walk and since you are 143, we'll have an ensemble of 143 independent random walks.

- You will set yourselves in a straight line, side by side, along a white line that will be marked on the ground with a chalk. Each of you will perform a 1D random walk, i.e. will move forward and backwards with random steps along the straight line that passes between your feet and perpendicular to the white chalk line. Figure 1 should give you some sort of idea. **Your initial position on the white chalk line, is your *zero* position on the x-axis** (drawn as a red line in Fig. 1), at each time you can move forward with a $+1$ step and backwards with a -1 step, relative to the zero position. You will be moving only along this x-axis, you cannot make steps to the side, that is why this is a *one-dimensional* random walk.

- To simulate the *randomness* of your steps, each of you will have a **quarter** to flip: **you will flip your coin at each time step**: if you get heads you go forward one step $+1$, if you get tails, you go one step back -1. Since we assume the coins to be fair coins, this will implement a random walk with probability $p = 1/2$, that means equal probability to move forward and backwards.

- To better visualize your role, you can imagine that you are a protein searching its target up and down on a line of DNA, to some extent this can be simplified as a 1D random walk. Similary you could be a single channel in an electronic device as an amplifier, subjected to external white noise, your signal fluctuates up and down as a 1D random walk. You could be the price of a stock-market, that everyday goes up and down unpredictably. You could be a completely disoriented drunk (English) soccer fan whose steps are random in space.

WHAT YOU NEED TO DO BEFORE THE ACTIVITY

In order to save time and collect the data ahead of time, instead of asking you to flip your coin while standing in Becton Plaza, we ask you to do it in advance at home. Since we will perform a 1D random walk of 10 time steps, we'll ask you before class to:

- in the comfort if your own room, **take a quarter and flip it 10 times**, **record in the table** here below your outcomes in the second column ($+1$ or -1), (either print this page and fill it out, or just copy the table on a piece of paper which you must bring to Becton plaza on Monday morning), these will be the single steps you will perform at each corresponding time step in Becton plaza[1].

- in the third column of the table write for each time step t the total sum of the steps up to that time, this will be the position of your random walker at time t (e.g. if you get -1 and -1 for the first two coin flips, position at time $t = 2$ is -2).

- **by Sunday, 6pm, go to Learning Catalytics** and plug in your position values at time $t = 3, 6, 10$ (as indicated in bold in the table). (It is **extremely important** that **all** of you do this before Sunday 6pm, we need to collect all your positions ahead of time to make your activity on Monday effective, and to have a significant statistical ensemble. If you don't submit your data on LC you will not be able to participate to the activity).

- (printed or copied on a piece of paper) **bring this table (filled with your data) with you to Becton Plaza** on Monday morning.

t (time step)	coin outcome (± 1)	position
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

WHAT ARE WE GOING TO DO

- As you come in to Becton Plaza, **arrange yourselves along the white chalk line**, ready to start, keep the table sheet in your hand so that you can read from it the random steps that you are going to perform.

- we'll count the time steps by playing a *gong*, **for each gong sound you will make a step as marked on your table** for the corresponding time (for instance.: $t = 1$, +1, $t = 2$, -1, $t = 3$, -1, etc.). There will be some tiles on the ground, **the size of *one* step is given by the length of *one* tile**.

- **Zen-moments:** we will make 3 steps, and then **stop at t = 3**, we'll pause for a bit of time: during this time **without moving from your position**, look around and observe how your classmates are distributed in space, ask yourself the two following questions:

  1) *What is the average/mean position over the ensemble of people?* i.e. considering the positive and negative positions along the x-axis, where is everybody standing *on average*?

  2) Now think about the *standard deviation* σ, can you give an estimate for the standard deviation of the distribution? Consider two standard deviations, 2σ, as the width of the distribution such that *most of the people* stand within this width. More precisely, define 2σ as the space within which there is 75% of the people.

- after this zen-moment, the gong will start again for other 3 steps, so you will move for $t = 4, 5$ and 6 and then we will **stop again at t = 6**, another zen-moment, as above look and observe around you and try to think about the questions 1) and 2).

- we'll start again for the last four steps, $t = 7, 8, 9, 10$, and **we'll finally stop at t = 10** for the final zen-moment. Enjoy a minute of reflection, think about questions 1) and 2) and meditate about what you have just experienced...

- then **head over** to the TEAL classroom where we will analyze your data in more details and continue the activity.

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[1] if for any reason, you will not be able to stand and walk and perform the random walk on Monday, please still flip your coins, submit your data in LC, and come to Becton plaza to observe the activity from the outside.