DEBUGGING

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Everyone Writes Code With Bugs

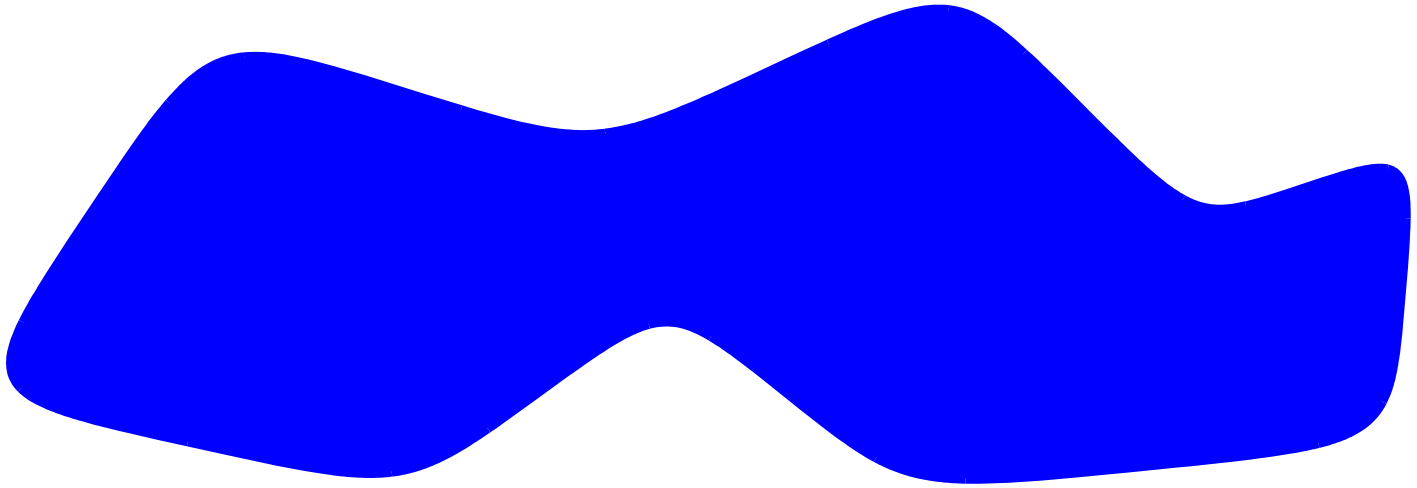
- Being able to quickly squash can radically increase productivity
- But how to do it?

Everyone Writes Code With Bugs

- Being able to quickly squash can radically increase productivity
- But how to squash bugs?
  - — A poor or beginning programmer will often:
  - — Stare at the code for a long time
  - — Make a random change (“voodoo programming”)
  - — Try the test again, watch it fail
  - — Repeat until exhausted
  - — Then, s/he’ll blame the compiler/faulty memory/FP error, etc.

Experienced and Skilled Programmers

- Tend not to change any code until they know what the problem is
  - — That is, they actively avoid vodoo programming, knowing it's a waste of time
  - — (Though even the best programmers lose their cool sometimes!)
- So how do they debug?
  - — They imagine the space of possible things that can go wrong:



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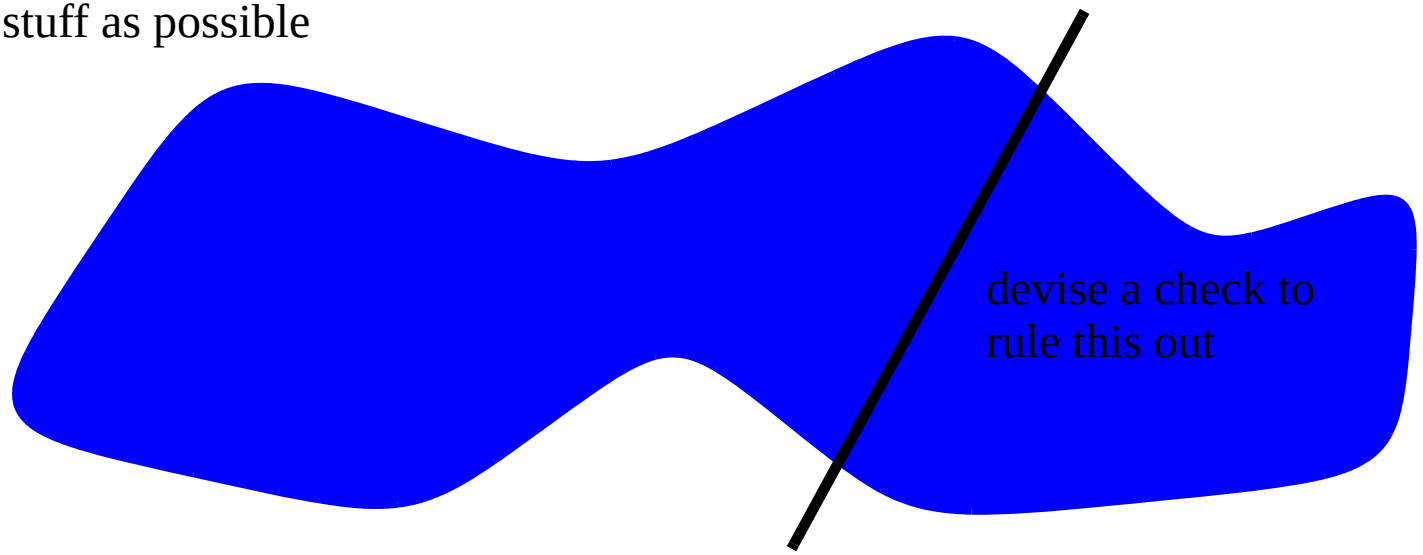
- So how do they debug?
  - — They come up with a sanity check that can slice off as much of the space of bad stuff as possible



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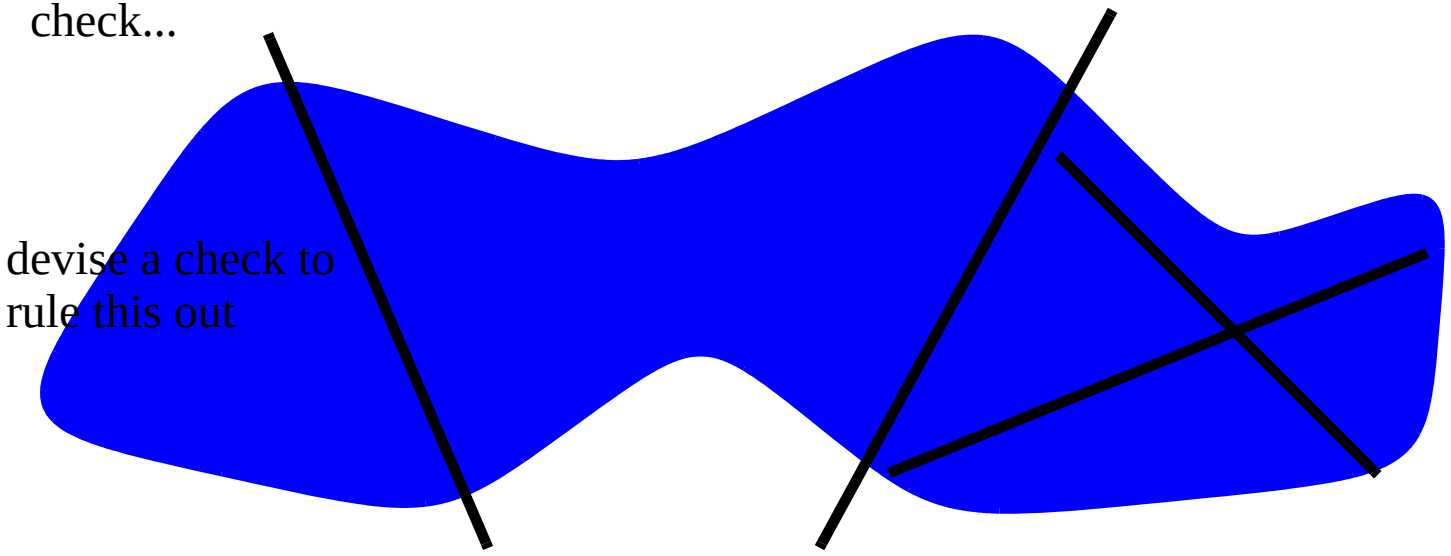
- So how do they debug?
  - — Pass the check? Then rule out that problem and all its causes. Then, devise another check...



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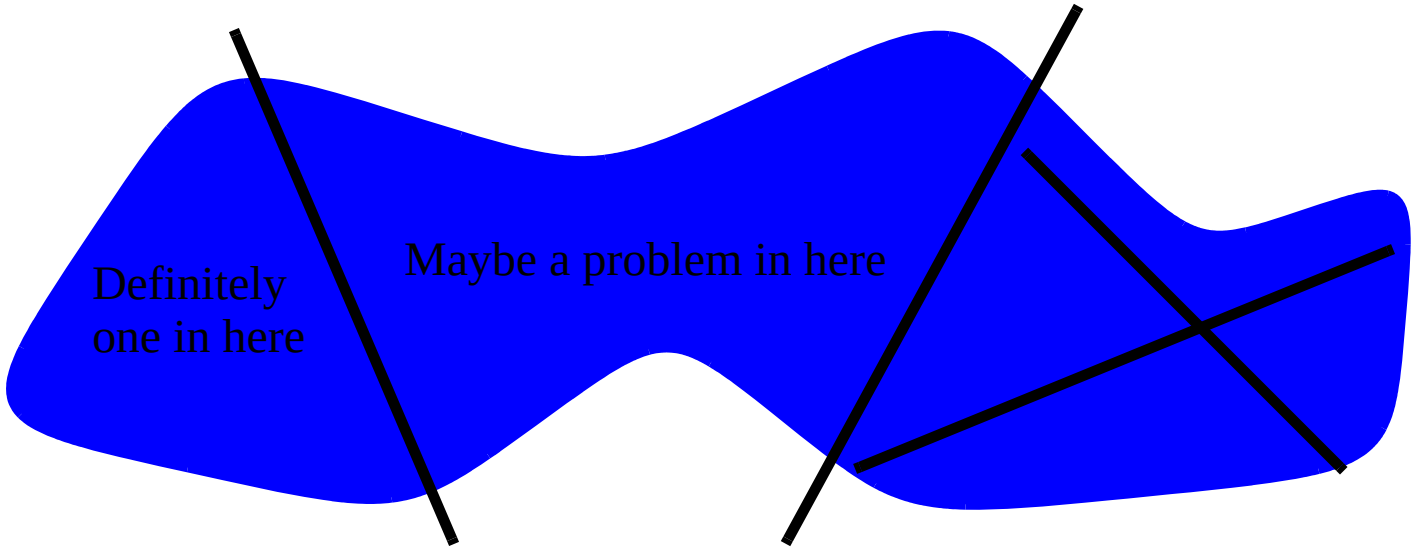
- So how do they debug?
  - — Fail the check? You know there is a problem in here...



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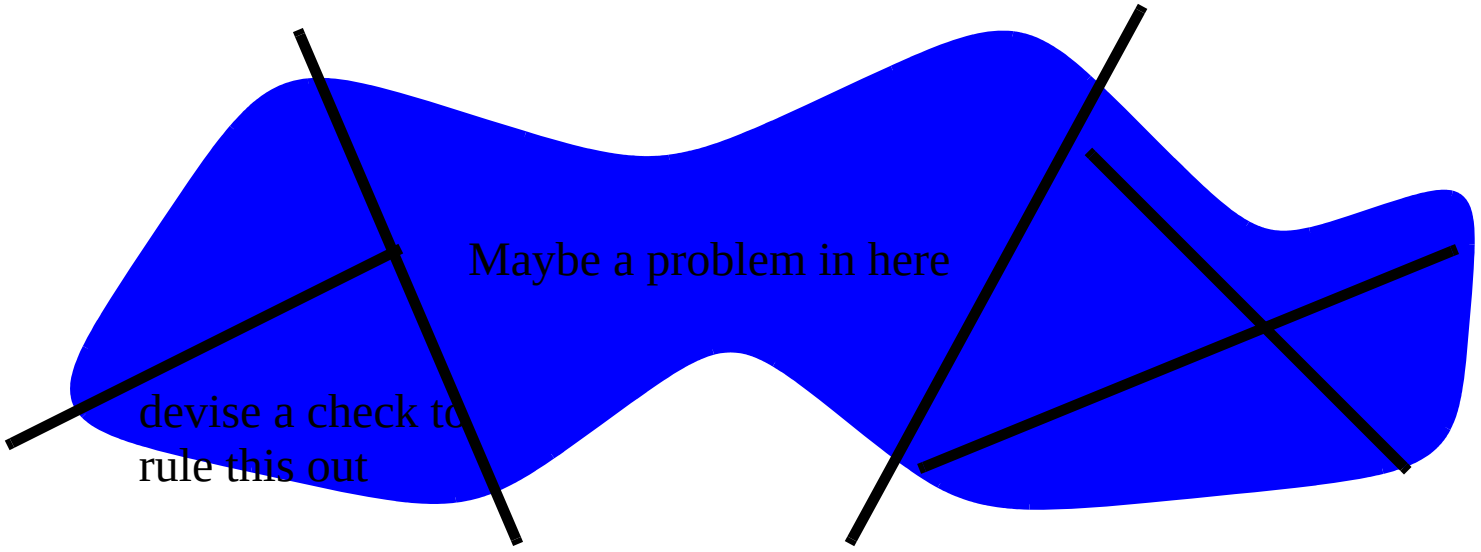
- Tend not to change any code until they know what the problem is
  - — That is, they actively avoid voodoo programming, knowing it's a waste of time
  - — (Though even the best programmers lose their cool sometimes!)
- So how do they debug?
  - — So keep going...



Key: Be Systematic and Thoughtful

- Your sanity check should always remove as much of the space of possible problems as is possible
- In vodoo programming, you are removing almost nothing
  - — When (in despiratoin) you change:

```
x.thisIsMyCode (a, b, c);
```

  - — To:

```
y.thisIsMyNewCode (c);
```

  - — You are examining only the possibility that the real problem was that the first one needed to be replaced with the second. How is that useful?

When You Are Debugging

- Heed the advice of Sherlock Holmes:

  "How often have I said that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?"

What Do These Checks Look Like?

- Most often they are bits of code that print some program state
- Sometimes, they are very complicated, and involved writing many (hundreds of?) SLOC to gather and distill that state
- Debuggers can sometimes be useful
  - — Because you can interactively check program state
  - — But if the check involves more than just checking the state of some objects...
  - — It's often better to just write some code and eschew the debugger
  - — Debuggers are especially useful for languages with pointers and w/o good exception handling (for example, C)
  - — But don't use 'em much myself when writing Java code

Let’s Look At an Example From A4

- Here’s the output from one of the test cases:

```
testMultinomial1:

"Got 33791.99999, expected 0.0 when I was checking the total
distance..."
```

Carefully Look At the Context of the Error

"Got 33791.99999, expected 0.0 when I was checking the total distance..."

```
testMultinomial1:

      int len = 100;
      SparseDoubleVector probs = new SparseDoubleVector (len, 0.0);
      for (int i = 0; i < len; i += 2) {
        probs.setItem (i, i);
      }
      probs.normalize ();

      // now, set up a distribution
      IRandomGenerationAlgorithm<IDoubleVector> myRNG =
        new Multinomial (27, new MultinomialParam (1024, probs));

      // and check the mean...
      DenseDoubleVector expectedMean = new DenseDoubleVector (len, 0.0);
      DenseDoubleVector expectedStdDev = new DenseDoubleVector (len, 0.0);
      for (int i = 0; i < len; i++) {
        expectedMean.setItem (i, probs.getItem (i) * 1024);
        expectedStdDev.setItem (i, Math.sqrt (probs.getItem (i) *
             1024 * (1.0 - probs.getItem (i))));
      }

      checkMeanAndVar (myRNG, expectedMean, expectedStdDev,
            5.0, 5.0, 5000, "multinomial number one");
```

Carefully Look At the Context of the Error

"Got 33791.99999, expected 0.0 when I was checking the total distance..."

Key question:
How could I possibly be off by 30K with 1024 trials?
Unless the # of trials is incorrect...

testMultinomial1:

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       1024 * (1.0 - probs.getItem (i))));
}

checkMeanAndVar (myRNG, expectedMean, expectedStdDev,
       5.0, 5.0, 5000, "multinomial number one");
```

Start By Looking At checkMeanAndVar

```
IDoubleVector firstOne = myRNG.getNext ();
DenseDoubleVector meanObs = new DenseDoubleVector (firstOne.getLength (), 0.0);
DenseDoubleVector stdDevObs = new DenseDoubleVector (firstOne.getLength (), 0.0);

// add in a bunch more
for (int i = 0; i < numTrials; i++) {
  IDoubleVector next = myRNG.getNext ();
  next.addMyselfToHim (meanObs);
  for (int j = 0; j < next.getLength (); j++) {
    stdDevObs.setItem (j, stdDevObs.getItem (j) + next.getItem (j) *
         next.getItem (j));
  }
}

// divide by the number of trials to get the mean
for (int i = 0; i < meanObs.getLength (); i++) {
  meanObs.setItem (i, meanObs.getItem (i) / numTrials);
  stdDevObs.setItem (i, Math.sqrt (stdDevObs.getItem (i) / numTrials -
       meanObs.getItem (i) * meanObs.getItem (i)));
}

// see if the mean and var are acceptable
checkTotalDiff (meanObs, expectedMean, errorMean,
         "total distance from true mean", dist);
checkTotalDiff (stdDevObs, expectedStdDev, errorStdDev,
         "total distance from true standard deviation", dist)
```

Add In a Check on the Number of Trials

```
IDoubleVector firstOne = myRNG.getNext ();
DenseDoubleVector meanObs = new DenseDoubleVector (firstOne.getLength (), 0.0);
DenseDoubleVector stdDevObs = new DenseDoubleVector (firstOne.getLength (), 0.0);

// add in a bunch more
double len = 0;
for (int i = 0; i < numTrials; i++) {
  IDoubleVector next = myRNG.getNext ();
  len += next.l1Norm ();
  next.addMyselfToHim (meanObs);
  for (int j = 0; j < next.getLength (); j++) {
    stdDevObs.setItem (j, stdDevObs.getItem (j) +
          next.getItem (j) * next.getItem (j));
  }
}
System.out.println ("avg number of balls found was " + len / numTrials);

// divide by the number of trials to get the mean
for (int i = 0; i < meanObs.getLength (); i++) {
  meanObs.setItem (i, meanObs.getItem (i) / numTrials);
  stdDevObs.setItem (i, Math.sqrt (stdDevObs.getItem (i) / numTrials -
        meanObs.getItem (i) * meanObs.getItem (i)));
}

// see if the mean and var are acceptable
checkTotalDiff (meanObs, expectedMean, errorMean,
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    stdDevObs.setItem (j, stdDevObs.getItem (j) +
          next.getItem (j) * next.getItem (j));
  }
}
System.out.println ("avg number of balls found was " + len / numTrials);

// divide by the number of trials to get the mean
for (int j = 0; j < meanObs.getLength (); j++) {
```

Output is:

"avg number of balls found was 1024.0"

Hmmm... how is this possible? We gotta look at the vecs

```
        "total distance from true mean", dist);
checkTotalDiff (stdDevObs, expectedStdDev, errorStdDev,
        "total distance from true standard deviation", dist)
```

So Add In Some Code To Print Them Out

```
IDoubleVector firstOne = myRNG.getNext ();
DenseDoubleVector meanObs = new DenseDoubleVector (firstOne.getLength (), 0.0);
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  next.addMyselfToHim (meanObs);
  for (int j = 0; j < next.getLength (); j++) {
    stdDevObs.setItem (j, stdDevObs.getItem (j) + next.getItem (j) *
        next.getItem (j));
  }
}

// divide by the number of trials to get the mean
for (int i = 0; i < meanObs.getLength (); i++) {
  meanObs.setItem (i, meanObs.getItem (i) / numTrials);
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        meanObs.getItem (i) * meanObs.getItem (i)));
}

// see if the mean and var are acceptable
checkTotalDiff (meanObs, expectedMean, errorMean,
         "total distance from true mean", dist);
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  next.addMyselfToHim (meanObs);
  for (int j = 0; j < next.getLength (); j++) {
    stdDevObs.setItem (j, stdDevObs.getItem (j) + next.getItem (j) *
        next.getItem (j));
  }
}

System.out.format ("\nfound: ");
// divide by the number of trials to get the mean
for (int i = 0; i < meanObs.getLength (); i++) {
  meanObs.setItem (i, meanObs.getItem (i) / numTrials);
  if (i < 10) {
    System.out.format (meanObs.getItem (i) + " ");
  }
  stdDevObs.setItem (i, Math.sqrt (stdDevObs.getItem (i) / numTrials -
           meanObs.getItem (i) * meanObs.getItem (i)));
}
System.out.format ("...\nexpected: ");
for (int i = 0; i < 10; i++) {
  System.out.format (expectedMean.getItem (i) + " ");
}
System.out.format ("...\n");
```

So Add In Some Code To Print Them Out

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        next.getItem (j));
  }
}

System.out.format ("\nfound: ");
// divide by the number of trials to get the mean
for (int i = 0; i < meanObs.getLength (); i++) {
  meanObs.setItem (i, meanObs.getItem (i) / numTrials);
  if (i < 10) {
```

Output is:

found: 0.0 0.0 0.8298 0.0 1.6868 0.0 2.5124 0.0 3.3072 0.0 ...

expected: 0.0 0.0 0.8359 0.8359 2.507 2.507 5.015 5.015 8.359 8.359 ...

```
  System.out.format (expectedMean.getItem (i) + " ");
}
System.out.format ("...\n");
```

expected can't be right...Is the test code wrong?

Back to testMultinomialOne

```
int len = 100;
SparseDoubleVector probs = new SparseDoubleVector (len, 0.0);
for (int i = 0; i < len; i += 2) {
  probs.setItem (i, i);
}
probs.normalize ();

// now, set up a distribution
IRandomGenerationAlgorithm<IDoubleVector> myRNG = new
   Multinomial (27, new MultinomialParam (1024, probs));

// and check the mean... we repeatedly double the prob vector to multiply it by 1024
DenseDoubleVector expectedMean = new DenseDoubleVector (len, 0.0);
DenseDoubleVector expectedStdDev = new DenseDoubleVector (len, 0.0);
for (int i = 0; i < len; i++) {
  expectedMean.setItem (i, probs.getItem (i) * 1024);
  expectedStdDev.setItem (i, Math.sqrt (probs.getItem (i) * 1024 *
          (1.0 - probs.getItem (i))));
}

checkMeanAndVar (myRNG, expectedMean, expectedStdDev, 5.0, 5.0,
       5000, "multinomial number one");
```

Let's print out the mean...

Back to testMultinomialOne

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int len = 100;
SparseDoubleVector probs = new SparseDoubleVector (len, 0.0);
for (int i = 0; i < len; i += 2) {
  probs.setItem (i, i);
}
probs.normalize ();
System.out.format ("expected right here: ");
for (int i = 0; i < 10; i++) {
  System.out.format (probs.getItem (i) * 1024 + " ");
}
System.out.format ("...");

// now, set up a distribution
IRandomGenerationAlgorithm<IDoubleVector> myRNG = new
   Multinomial (27, new MultinomialParam (1024, probs));

// and check the mean... we repeatedly double the prob vector to multiply it by 1024
DenseDoubleVector expectedMean = new DenseDoubleVector (len, 0.0);
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DenseDoubleVector expectedMean = new DenseDoubleVector (len, 0.0);
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```

Output is:

expected right here: 0.0 0.0 0.8359 0.0 1.6718 0.0 2.507 0.0 3.343 0.0 ...
found: 0.0 0.0 0.8298 0.0 1.6868 0.0 2.5124 0.0 3.3072 0.0 ...
expected: 0.0 0.0 0.8359 0.8359 2.507 2.507 5.015 5.015 8.359 8.359 ...

```
      5000, "multinomial number one");
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          (1.0 - probs.getItem (i))));
}

checkMeanAndVar (myRNG, expectedMean, expectedStdDev, 5.0, 5.0,
       5000, "multinomial number one");
```

How does this change going from here to here?

Let's See If It Does In Fact Change

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int len = 100;
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for (int i = 0; i < 10; i++) {
  System.out.format (expectedMean.getItem (i) + " ");
}
System.out.format ("...");
```

So these two do not match up. How is this possible?

The Only Reasonable Explanation…

```
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}
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for (int i = 0; i < 10; i++) {
  System.out.format (probs.getItem (i) * 1024 + " ");
}
System.out.format ("...");

// now, set up a distribution
IRandomGenerationAlgorithm<IDoubleVector> myRNG = new
   Multinomial (27, new MultinomialParam (1024, probs));

// and check the mean... we repeatedly double the prob vector to multiply it by 1024
DenseDoubleVector expectedMean = new DenseDoubleVector (len, 0.0);
DenseDoubleVector expectedStdDev = new DenseDoubleVector (len, 0.0);
for (int i = 0; i < len; i++) {
  expectedMean.setItem (i, probs.getItem (i) * 1024);
  expectedStdDev.setItem (i, Math.sqrt (probs.getItem (i) * 1024 *
          (1.0 - probs.getItem (i))));
}
System.out.format ("\nexpected mean: ");
for (int i = 0; i < 10; i++) {
  System.out.format (expectedMean.getItem (i) + " ");
}
System.out.format ("...");
```

Constructor is screwing with probs

Got It!

```
class Multinomial ...

  private IDoubleVector sums;

  public Multinomial (long seed, MultinomialParam myParams){
    super(seed);
    try {
      sums = myParams.getProbs ();
      double tot = 0.0;
      for (int i = 0; i < sums.getLength (); i++) {
        tot += sums.getItem (i);
        sums.setItem (i, tot);
      }
    } catch (OutOfBoundsException e) {...}
```

Got It!

```
public Multinomial (long seed, MultinomialParam myParams){
  super(seed);
  try {
    sums = myParams.getProbs ();
    double tot = 0.0;
    for (int i = 0; i < sums.getLength (); i++) {
      tot += sums.getItem (i);
      sums.setItem (i, tot);
    }
  } catch (OutOfBoundsException e) {...}
```

- Test code assumes you don’t mess with params
  - — Should this have been explicitly stated?
  - — Perhaps, but generally assumed you don’t change param state uness explicitly stated somewhere in doc that you can or will
  - — Regardless, we found the bug!
  - — To fix? Just allocate a new vector...

Questions?