Technical Slide

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- In this lesson:
  - Common types of test cases
  - Testing workflow
  - Stress-testing

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- **Reliability:** make sure that your program doesn't crash
- Asserts help — check invariants without correct answer
- **Limits:** check working time and memory on large inputs
- Locally — detailed information on perfomance

Sample tests

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- Test your understanding of the statement
- You could've gotten it wrong
- Test your solution before implementing
- Save time by realizing you're wrong earlier
- Samples check general correctness and sometimes special cases
- Do not rely on samples only!

Minimal test

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- Something else could be minimized, e.g. answer size

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- Integer overflow — if negative answer when should be nonnegative

How to obtain max test

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- Generate by another program

```
1  int n = 1000000;
2  cout << n << '\n';
3  for (int i = 0; i < n; ++i) {
4      cout << int(1e9) << ' ';
5  }
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- Plug in inside your code

```
1  int n;
2  //cin >> n;
3  n = 1000000;
4  for (int i = 0; i < n; ++i) {
5      //cin >> a[i];
6      a[i] = int(1e9);
7  }
```

- Better to have special function for reading data, to replace it as a whole

```
 1  void readInput() {
 2      cin >> n;
 3      for (int i = 0; i < n; ++i) {
 4          cin >> a[i];
 5      }
 6  }
 7  void setInput() {
 8      n = 1000000;
 9      for (int i = 0; i < n; ++i) {
10          a[i] = int(1e9);
11      }
12  }
13  int main() {
14      //readInput();
15      setInput();
16  }
```

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- Problems about divisibility — prime numbers, numbers with many divisors
  2, 3, 11, 31, 997, $10^9 + 7$ are prime
  48 has 10 divisors, 931 170 240 has 1344
- Graphs, geometry, ...

Program structure

- Test all branches in your code

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1 if (condition) {
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Include test with `condition` true, and `condition` false

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- Test different parts separately, each right after it's finished

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- Test different run patterns, special cases, pathological cases — depends on the solution and its proof
- Combine all of the above

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2. After submission — to find a test case for debugging

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- Depends on complexity and how sure you are in your solution
- Always check on samples — that your program works at all, and that the format is correct
- Nearly always test on cases other than samples

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  - Use some unit-testing software to manage tests, like JUnit

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- Write a *generator* program, which outputs some random input
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- Fully automated, thousands tests per second!

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- Obtain the correct answer via the trivial solution
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- In total — a small version of a testing system

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- Do not lose generality
  Strings of 'a' far less interesting than strings of 'a' and 'b'
- Correctly initialize random to get different tests

Stress-test for crashes

```
1  for (( test=1; ; test++ ))
2  do
3      echo Test $test
4      ./generate > in
5      ./solution < in > out
6      if [ $? -ne 0 ]
7      then
8          echo Runtime error
9          break
10     fi
11 done
```

Terminates on error, so error test is in the `in` file afterwards

Stress-test for correctness

```
1  for (( test=1; ; test++ ))
2  do
3      echo Test $test
4      ./generate > in
5      ./solution < in > out
6      ./solution_trivial < in > ans
7      diff out ans
8      if [ $? -ne 0 ]
9      then
10         echo Wrong answer
11         break
12     fi
13 done
```

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- No point if generator/trivial solution/checker is too complex
- Start with very small test sizes
- Couple of minutes running is usually enough
- While running do something else useful
- If nothing is found, generate larger tests
  Or rethink the generator

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- Test your solution before and after submitting
- Start with samples
- "Interesting" manual cases — min/max, problem type specific, and anything you could imagine
- Test different parts separately
- If everything else fails, run a stress-test
- Watch out for the generator
  Generate small tests