

# CS 6015: Software Engineering

Spring 2024

Lecture 8: Code Coverage

# This Week

- Defensive programming
- Testing / Code Coverage
- Homework 4

# Next Week

- Documentation
- Let Binding (Project related)
- Parsing (Project related)

# Project Related - MSDscript

- Two main parts:
  - Representation Classes (What we've been doing so far)
  - Parsing

# MSDscript: Representation Classes / methods

```
class Expr {  
public:  
  
    virtual bool equals(Expr *e) = 0;  
    virtual int interp() = 0;  
    . . .  
};
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
  
    . . .  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
  
    . . .  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
  
    . . .  
};
```

```
class Var : public Expr {  
public:  
    string var;  
  
    }  
    . . .  
};
```

# MSDscript: Grammar

$\langle \text{expr} \rangle$  =  $\langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle$  +  $\langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle$  \*  $\langle \text{expr} \rangle$   
|  $\langle \text{variable} \rangle$   
| **\_let**  $\langle \text{variable} \rangle$  =  $\langle \text{expr} \rangle$  **\_in**  $\langle \text{expr} \rangle$  **Coming soon**  
| .... More (later)

# MSDscript: Representation Classes / methods

```
class Expr {  
public:  
  
    virtual bool equals(Expr *e) = 0;  
    virtual int interp() = 0;  
    . . .  
};
```

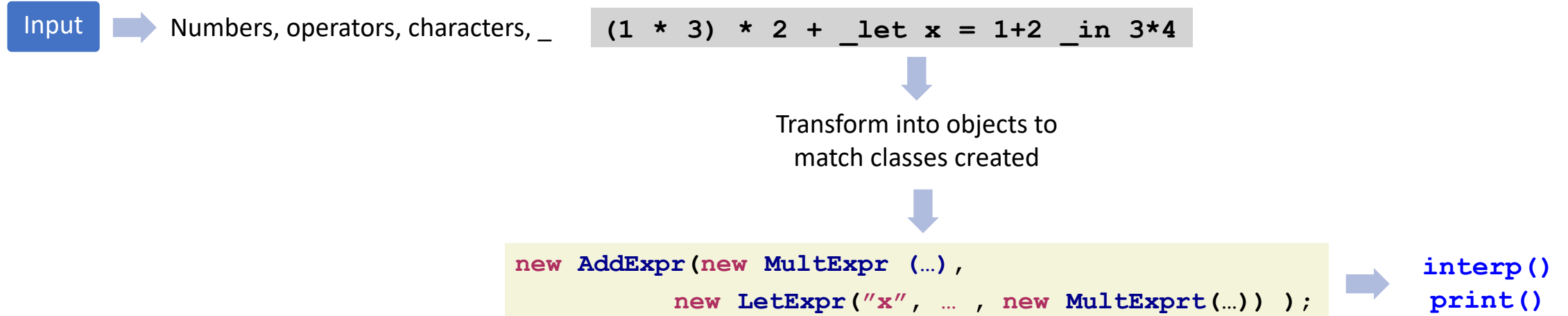
```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
  
    . . .  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
  
    . . .  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
  
    . . .  
};
```

```
class Var : public Expr {  
public:  
    string var;  
  
    }  
    . . .  
};
```

# MSDscript: Parsing



Strategy for parsing → ~~One string then  
Divide and Conquer~~

Stream of characters

# Next Week

- Extend the grammar to include **Let**
- Add class representation for the new grammar
- Parsing



# MSDscript: Representation Classes / methods

```
class Expr {  
public:  
  
    virtual bool equals(Expr *e) = 0;  
    virtual int interp() = 0;  
    . . .  
};
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
  
    . . .  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
  
    . . .  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
  
    . . .  
};
```

. . .

```
class Let : public Expr {  
public:  
  
    }  
  
    . . .  
};
```

# Plan

- Recall: Testing
- Code coverage
- Coverage types
- Code coverage in Xcode
- Continuous integration
  - GitHub actions

# Testing

- Our team leader / supervisor asked whether the test cases are sufficient.
- How to make sure that the tests cover all possible cases?
- How do you know whether a program is tested well?
- Recall from testing:
  - Random testing
    - Not sufficient
  - Exhaustive testing
    - Hard to achieve / time consuming
- Solution??

# Code coverage

- Describes how much of your code is executed while testing.
- Expression of the goodness of your test cases.
- Many metrics/notions are used:
  - Statement/Line coverage
  - Branch coverage
  - Path coverage
  - Function coverage
  - Loop coverage

# Statement/Line Coverage

```
int returnInput(int input, bool cond1, bool cond2, bool cond3){  
    int x = input;  
    int y = 0;  
  
    if (cond1)  
        x++;  
    if (cond2)  
        x--;  
    if (cond3)  
        y=x;  
  
    return y;  
}
```

Statement Coverage for `CHECK( returnInput(2, true, true, true) == 2 );` ?

Statement Coverage for `CHECK( returnInput(x, true, true, true) == x );` ?

# Statement/Line Coverage

- Refers to the percentage of statements in the code that have been executed by the test cases

```
int returnInput(int input, bool cond1, bool cond2, bool cond3){  
    int x = input;  
    int y = 0;  
  
    if (cond1)  
        x++;  
    if (cond2)  
        x--;  
    if (cond3)  
        y=x;  
  
    return y;  
}
```

Statement Coverage for CHECK( returnInput(2, true, true, true) == 2 );

Statement Coverage for CHECK( returnInput(x, true, true, true) == x );

**100%**

# Branch Coverage

```
int returnInput(int input, bool cond1, bool cond2, bool cond3){  
    int x = input;  
    int y = 0;  
  
    if (cond1)  
        x++;  
    if (cond2)  
        x--;  
    if (cond3)  
        y=x;  
  
    return y;  
}
```

Branch Coverage for `CHECK( returnInput(2, true, true, true) == 2 );` ?

Branch Coverage for `CHECK( returnInput(x, true, true, true) == x );` ?

# Branch Coverage

- Refers to the percentage of branches that have been executed; Each possible branch counted separately

```
int returnInput(int input, bool cond1, bool cond2, bool cond3){  
    int x = input;  
    int y = 0;  
  
    if (cond1)  
        x++;  
    if (cond2)  
        x--;  
    if (cond3)  
        y=x;  
  
    return y;  
}
```

Branch Coverage for CHECK( returnInput(2, true, true, true) == 2 );

Branch Coverage for CHECK( returnInput(x, true, true, true) == x );

**50%**



# Branch Coverage

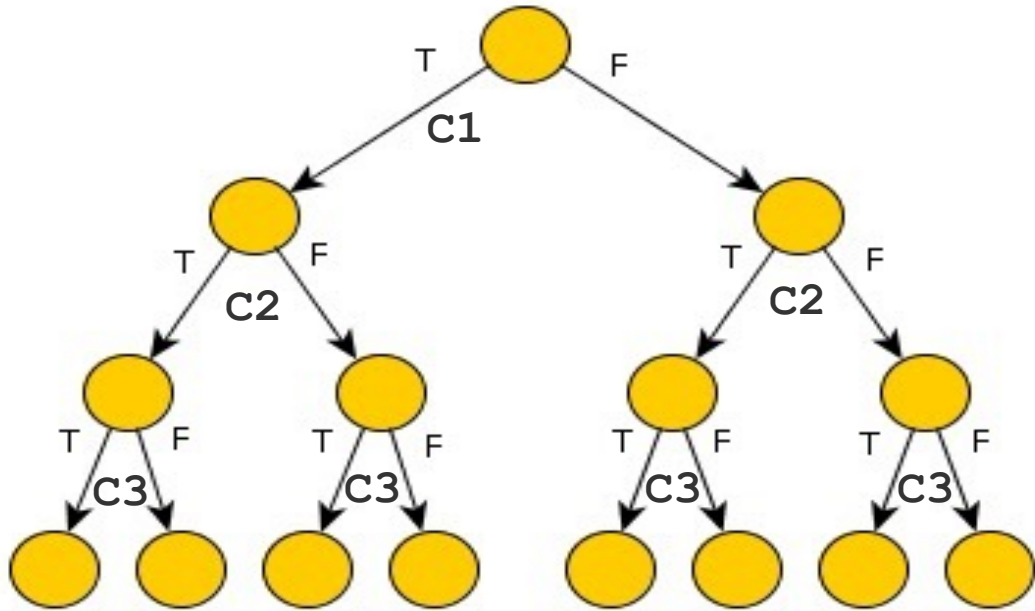
- Refers to the percentage of branches that have been executed; Each possible branch counted separately
- An “if” statement has 2 branches (even if there is not “else” statement):
  - a branch that executes when the condition is true, and
  - a branch that executes when the condition is false
- A “switch” can have many branches

# Path Coverage

```
int returnInput(int input, bool cond1, bool cond2, bool cond3){  
  
    int x = input;  
    int y = 0;  
  
    if (cond1)  
        x++;  
    if (cond2)  
        x--;  
    if (cond3)  
        y=x;  
  
    return y;  
}
```

Path Coverage for `CHECK( returnInput(AnyNum, true, true, true) == AnyNum ); ?`

# Path Coverage



```
int returnInput(int input, bool cond1,
bool cond2, bool cond3){
```

```
int x = input;  
int y = 0;
```

```
if (cond1)
    x++;
if (cond2)
    x--;
if (cond3)
    y=x;
```

```
return y;
```

}

Path Coverage for `CHECK( returnInput(AnyNum, true, true, true) == AnyNum );`

## 1/8 path coverage

# Function Coverage

```
int returnInput(int input, bool cond1, bool
cond2, bool cond3){

    int x = input;
    int y = 0;

    if (cond1)
        x++;
    if (cond2)
        x--;
    if (cond3)
        y=x;

    return y;
}
```

```
int max(int n, int m) {
    if (n > m)
        return n;
    else
        return m;
}
```

```
int maxabs(int n, int m) {
    int absn = ((n < 0) ? -n : n);
    int absm = ((m < 0) ? -m : m);
    if (absn == absm)
        return absn;
    else
        return max(absn, absm);
}
```

Function Coverage for:

CHECK( returnInput(x, true, true, true) == x );

CHECK( max(100, 50) == 100 );

**2/3 functions called**

# Function Coverage

✓

```
int returnInput(int input, bool cond1, bool
cond2, bool cond3){

    int x = input;
    int y = 0;

    if (cond1)
        x++;
    if (cond2)
        x--;
    if (cond3)
        y=x;

    return y;
}
```

✓

```
int max(int n, int m) {
    if (n > m)
        return n;
    else
        return m;
}
```

✓

```
int maxabs(int n, int m) {
    int absn = ((n < 0) ? -n : n);
    int absm = ((m < 0) ? -m : m);
    if (absn == absm)
        return absn;
    else
        return max(absn, absm);
}
```

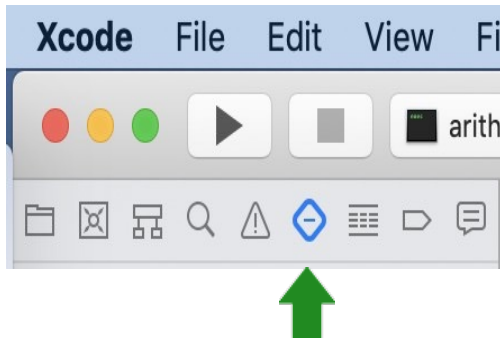
**100%** Function Coverage when every function is called

# Code coverage vs Test coverage

- Code coverage
  - Verifies the extent to which the code has been executed
  - Levels: Line/branch/path/function/....
- Test coverage
  - Measures how much of the feature set is covered
  - Types: Feature/Risk/Requirements

# Testing in Xcode

Start by clicking here:



Then click “+” in the bottom left Select “New Unit Test Target...”

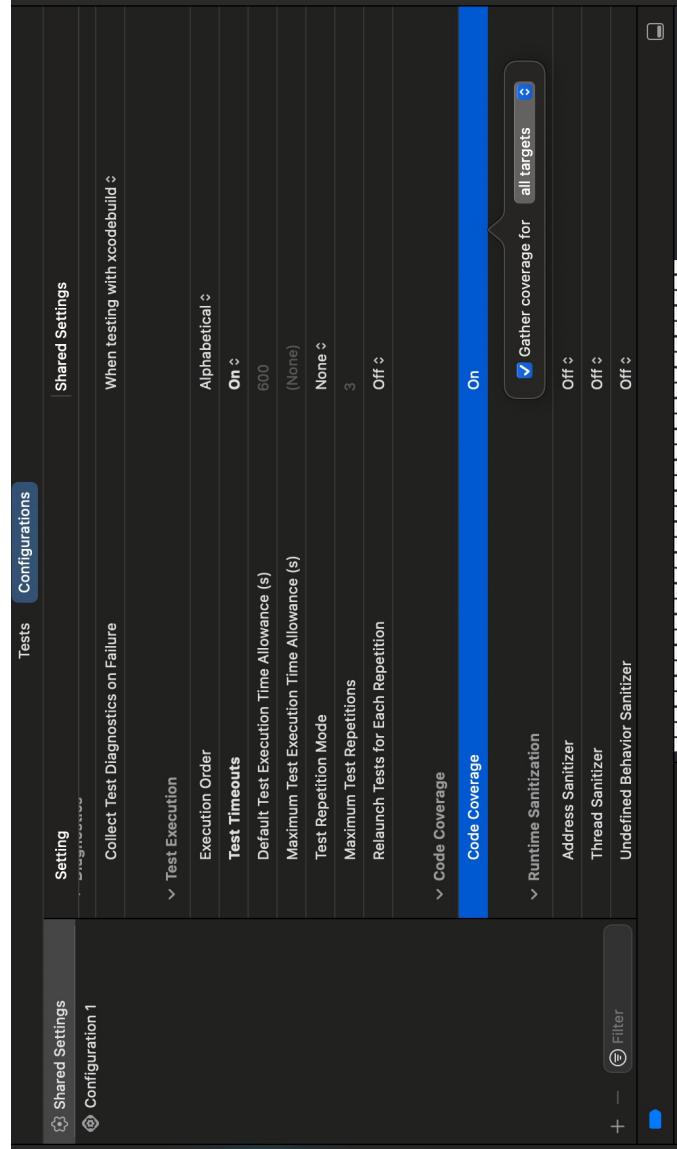
*If it shows Missing Test Plan, then you need to create new Test Plan*

Pick “Objective-C” for the language

All of the project changes are part of the project that you probably have checked in to your Git repo

# Testing in Xcode

Enable code coverage (Found under Configuration of your Test Plan):

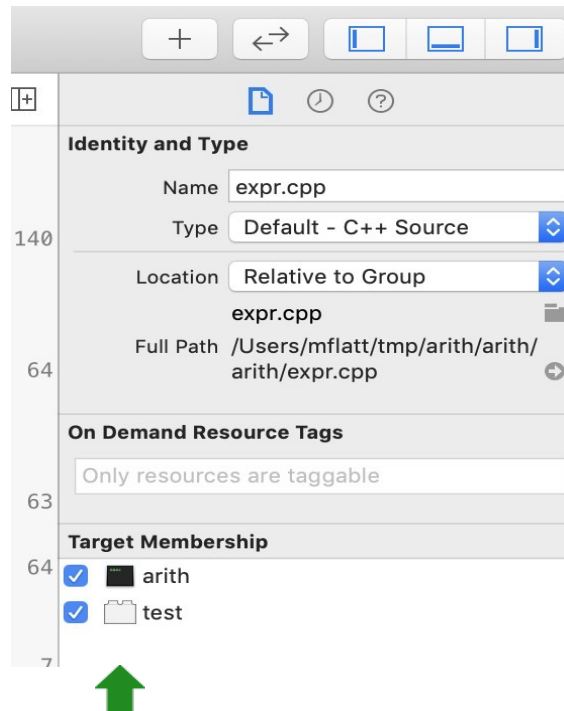




# Testing in Xcode

For each non-main file, add to your new test target:

- click on the file and check the Target Membership
- or right click then show file inspector



# Testing in Xcode

Adjust created .m file:

```
#import <XCTest/XCTest.h>
#include "run.hpp"

@interface test : XCTestCase
@end

@implementation test
- (void)testAll {
    if (!run_tests())
        XCTFail(@"failed");
}
@end
```

# Testing in Xcode

Add glue code in new file **run.hpp**:

```
extern bool run_tests(void) ;
```

Add glue code in new file **run.cpp**:

```
extern "C" {  
    #include "run.hpp"  
};  
  
#define CATCH_CONFIG_RUNNER  
#include "../directory/catch.h"  
  
bool run_tests() {  
    const char *argv[] = { "test" };  
    return (Catch::Session().run(1, argv) == 0);  
}
```

# Testing in Xcode

- Use **Test** ⌘U instead of **Run** ⌘R from the **Project** menu
- or switch to Test Plan, then right click and run testAll
- Turn on **Code Coverage** in the **Editor** menu
- Look for pink bars along the right edge of your code ⇒ uncovered

# Continuous Integration

# Continuous Integration (CI)

*Continuous integration is the practice of running the steps that were traditionally performed during “integration” little and often throughout the development process, rather than waiting until code is complete before bringing it all together and testing it.*

**Ref:** <https://www.jetbrains.com/teamcity/ci-cd-guide/continuous-integration-vs-delivery-vs-deployment/>

# GitHub Actions

You should always run your tests, but computers are good at remembering things that people forget

- On Github: **Actions** → **set up a workflow yourself**
- Use this text:

```
name: MSD
on:
  push:
jobs:
  build:
    runs-on: macos-latest
    steps:
      - name: Checkout v1
        uses: actions/checkout@v1
      - name: Run test
        run: make test
```

# GitHub Actions

You should always run your tests, but computers are good at remembering things that people forget

- On Github: **Actions** → **set up a workflow yourself**
- Use this text:

```
name: MSD
on:
  push:
jobs:
  build:
    runs-on: macos-latest
    steps:
      - name: Checkout v1
        uses: actions/checkout@v1
      - name: Run test
        run: make test
        working-directory: path/to/dir
```

If your **source files** and the **Makefile** is in **path/to/dir** within the repo, add:

**working-directory: path/to/dir**

Don't include starting slash or the name of your repo directory



# GitHub Actions more

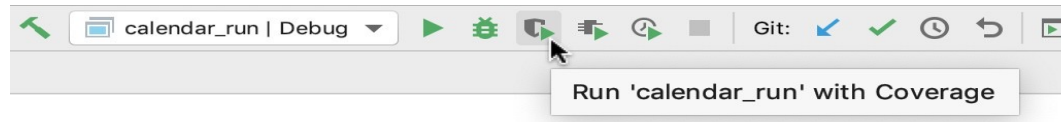
```
name: MSD
on:
  push:
    branches:
      - main
jobs:
  build:
    runs-on: macos-latest
    strategy:
      matrix: { dir: ['lab3', 'homework4'] }
    steps:
      - name: Checkout v1
        uses: actions/checkout@v1
      - name: Run test
        run: make test
        working-directory: ${ matrix.dir }
```

Adding GitHub actions for each folder

# Testing in CLion

# Testing in CLion

To run with coverage:



First run:

Could not find code coverage data  
Make sure the target application is compiled with the required compiler options  
Would you like to add them automatically?  
[Fix and rerun](#)

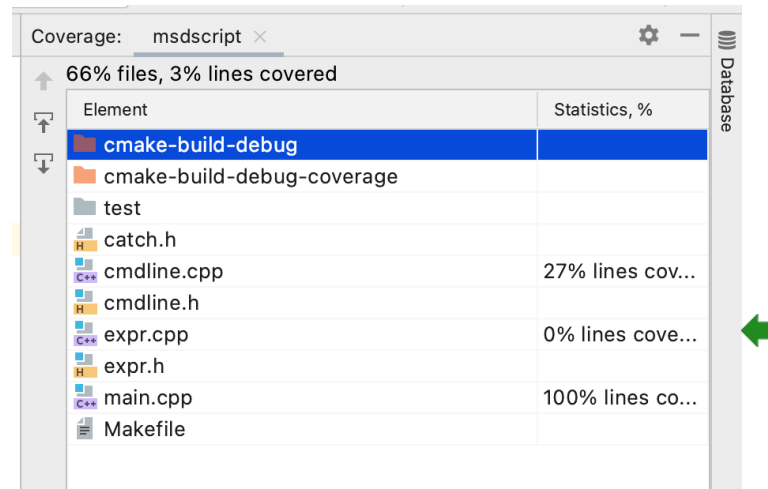
Click **Fix and rerun**

<https://www.jetbrains.com/help/clion/code-coverage-clion.html>

Beware: some changes will affect only your project workspace, which you probably exclude from your Git repo

# Testing in CLion

When you run with coverage (again), probably the interesting file has 0% coverage:



The screenshot shows the CLion Coverage window for a project named 'msdscript'. The window title is 'Coverage: msdscript'. Below the title bar, it says '66% files, 3% lines covered'. The main area is a table with two columns: 'Element' and 'Statistics, %'. The table lists several files and folders. The file 'expr.cpp' is highlighted with a green arrow pointing to its '0% lines covered' status. The file 'main.cpp' shows '100% lines covered'. The folder 'cmake-build-debug' is selected in the left sidebar.

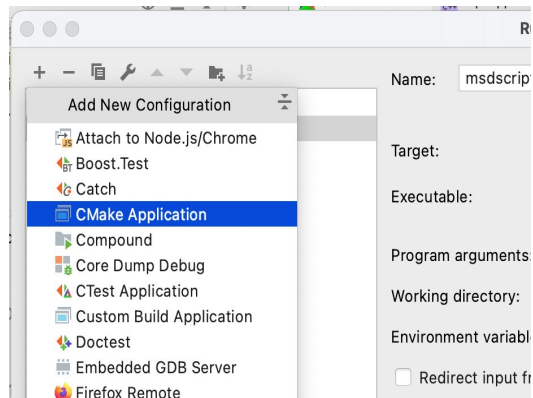
Element	Statistics, %
cmake-build-debug	
cmake-build-debug-coverage	
test	
catch.h	
cmdline.cpp	27% lines cov...
cmdline.h	
expr.cpp	0% lines cove...
expr.h	
main.cpp	100% lines co...
Makefile	

That's because no tests were run

# Testing in CLion

Add **--test** when running with coverage:

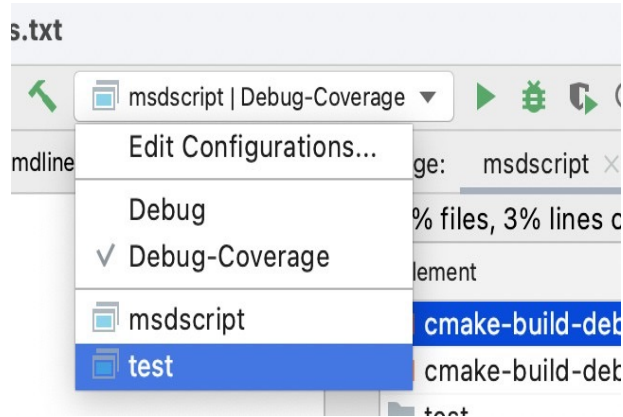
- Go to **Run** → **Edit Configurations...**
- Click **+** and add a new **CMake Application**



- Name it something like **test**
- Set the **Program arguments:** field to **--test**

# Testing in CLion

- Pick the **test** configuration while keeping **Debug-Coverage** still checked



- Run with coverage again, and since your program runs the test suite when **--test** is the argument, now you get useful coverage
- Look for pink bars along the editor left edge to find uncovered lines