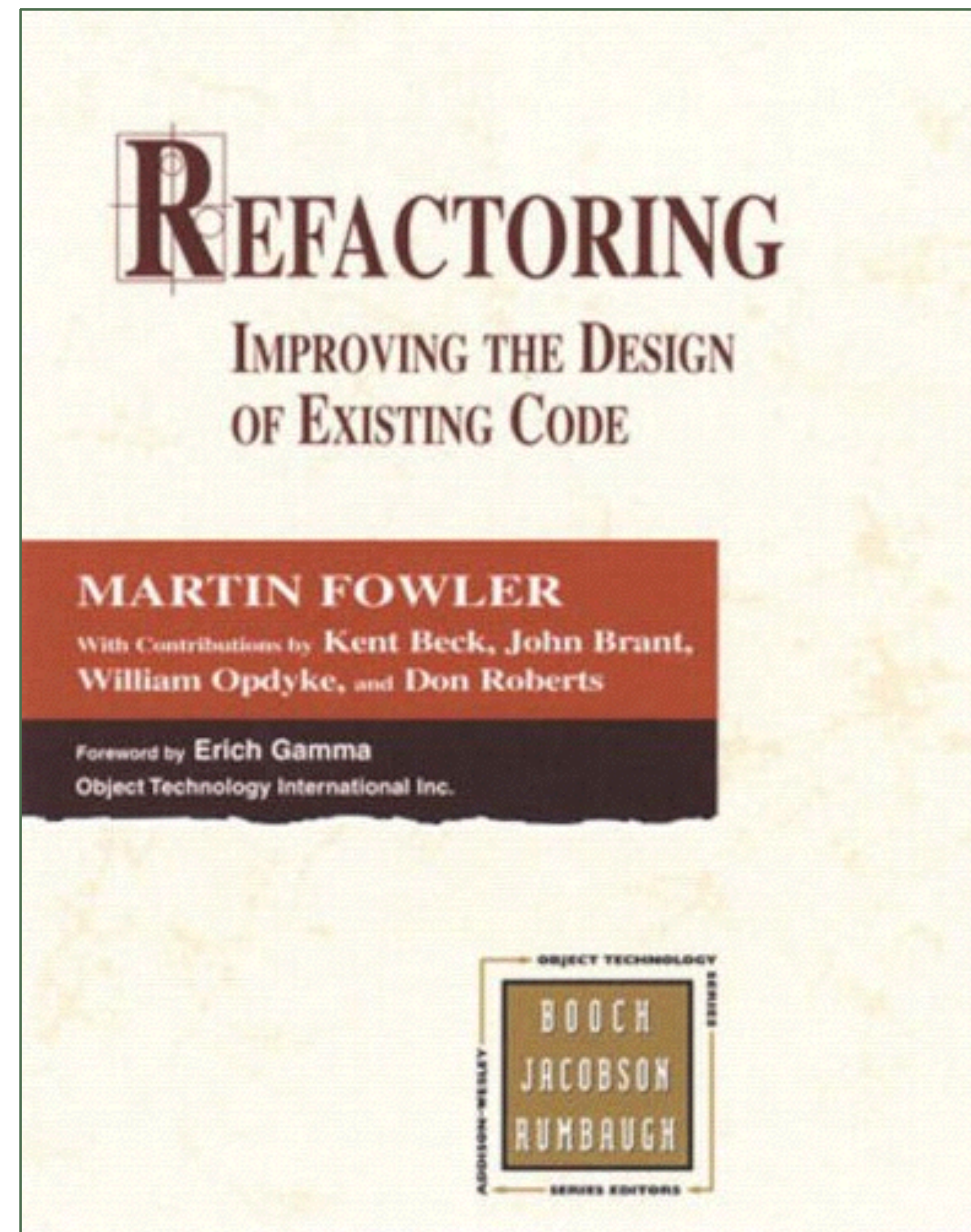
REFACTORING

Allowing design to emerge!

Good sources…

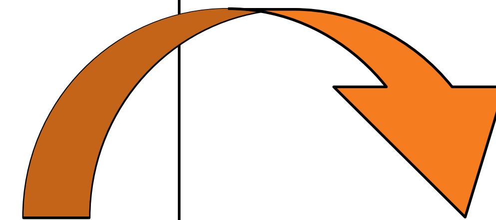


Overview

- Introduction
- What is a “Code Smell”?
- Examples…
- What do you do in response to a code smell? Refactor!
- What is a “refactoring”?
    - When to do it… when not to do it…
- Good refactoring process
- Examples…
- A little practice
- Resources & Summary

Change is constant

```java
public String printStatement() {
    double totalAmount = 0;
    Enumeration rentals = _rentals.elements();
    while (rentals.hasMoreElements()) {
        double thisAmount = 0;
        Rental each = (Rental) rentals.nextElement();

        //determine amount for each movie
        switch (each.getMovie().getPriceCode()) {
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() > 2)
                thisAmount += (each.getDaysRented() - 2) * 1.5;
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDaysRented() * 3;
            break;
        }

        totalAmount += thisAmount;
    }

    return "Amount owed: "+ totalAmount+"";
}
```



...becomes:

```
public String printStatement() {
    double totalAmount = 0;
    Enumeration rentals = _rentals.elements();
    while (rentals.hasMoreElements()) {
        double thisAmount = 0;
        Rental each = (Rental) rentals.nextElement();

        //determine amount for each movie
        switch (each.getMovie().getPriceCode()) {
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() > 2)
                thisAmount += (each.getDaysRented() - 2) * 1.5;
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDaysRented() * 3;
            break;
        }

        totalAmount += thisAmount;
    }

    return "Amount owed: "+ totalAmount+"";
}
```

```
public String printStatement() {
    double totalAmount = 0;
    int frequentRenterPoints = 0;
    Enumeration rentals = _rentals.elements();
    String result = "Rental Record for " + getName() + "\n";

    while (rentals.hasMoreElements()) {
        double thisAmount = 0;
        Rental each = (Rental) rentals.nextElement();

        //determine amounts for each line
        switch (each.getMovie().getPriceCode()) {
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() > 2)
                thisAmount += (each.getDaysRented() - 2) * 1.5;
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDaysRented() * 3;
            break;
        case Movie.CHILDRENS:
            thisAmount += 1.5;
            if (each.getDaysRented() > 3)
                thisAmount += (each.getDaysRented() - 3) * 1.5;
            break;
        }

        // add frequent renter points
        frequentRenterPoints++;
        // add bonus for a two day new release rental
        if ((each.getMovie().getPriceCode() == Movie.NEW_RELEASE) && each.getDaysRented() > 1)
            frequentRenterPoints++;

        // show figures for this rental
        result += "\t" + each.getMovie().getTitle() + "\t" + String.valueOf(thisAmount) + "\n";
        totalAmount += thisAmount;
    }

    // add footer lines
    result += "Amount owed is " + String.valueOf(totalAmount) + "\n";
    result += "You earned " + String.valueOf(frequentRenterPoints) + " frequent renter points";

    return result;
}
```

and then becomes…

```
public String printStatement() {
    double totalAmount = 0;
    Enumeration rentals = _rentals.ele
    while (rentals.hasMoreElements())
        double thisAmount = 0;
        Rental each = (Rental) rentals

        //determine amount for each mo
        switch (each.getMovie().getPri
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() >
                thisAmount += (each.ge
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDays
            break;
        }

        totalAmount += thisAmount;
    }

    return "Amount owed: "+ totalAmour
}
```

```
public String printStatement() {
    double totalAmount = 0;
    int frequentRenterPoints = 0;
    Enumeration rentals = _rentals.elements();
    String result = "Rental Record for " + getName() + "\n";

    while (rentals.hasMoreElements()) {
        double thisAmount = 0;
        Rental each = (Rental) rentals.nextEle

        //determine amounts for each line
        switch (each.getMovie().getPriceCode()
        case Movie.REGULAR:
            thisAmount += 2;
            if (each.getDaysRented() > 2)
                thisAmount += (each.getDaysRen
            break;
        case Movie.NEW_RELEASE:
            thisAmount += each.getDaysRented()
            break;
        case Movie.CHILDRENS:
            thisAmount += 1.5;
            if (each.getDaysRented() > 3)
                thisAmount += (each.getDaysRen
            break;
        }

        // add frequent renter points
        frequentRenterPoints++;
        // add bonus for a two day new release
        if ((each.getMovie().getPriceCode() ==
            frequentRenterPoints++;

        // show figures for this rental
        result += "\t" + each.getMovie().getTi
        totalAmount += thisAmount;
    }

    // add footer lines
    result += "Amount owed is " + String.valueOf(totalAmount) + "\n";
    result += "You earned " + String.valueOf(frequentRenterPoints) + " frequent renter points";

    return result;
}
```

You might then add another method "printLongFormStatement" that reuses a lot of this code. And since you are in a hurry, you might just copy this method, and augment it.

don't pretend you haven't done this

So the code changes…

- It's possible you (who are a perfect programmer) never introduces duplication into your code.
- But:
    - Others alter your code
    - You alter other people's code
    - This is good: collaboration = better product!

And code issues <u>emerge</u>

<u>*And are **expected** in agile methodologies!*</u>

Code issues like:

- duplication
- rigidity
- lack of reusability
- mess

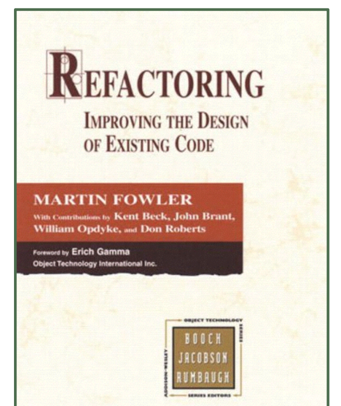
Gradually, code begins to rot in places.

Those places are said to “smell”

We, as designers/software developers, have to chase down these code smells and fix them.

What is a “Code Smell”?

- A recognizable indicator that something may be wrong in the code
- Can occur in the product code as well as in the test code!



The smells/refactorings in the following slides are from Martin Fowler, Refactoring, “Improving the design of existing code”.
For test code smells: van Deursen et al. “Refactoring Test Code”.

Some common issues

- Magic Numbers
- Duplicated Code
- Long Method
- Complicated Conditionals
- Switch Statements/Type Conditionals
- Large class (doing the work of two)
- Divergent Change
- Shotgun Surgery
- Comments

within-class smells

between-class smells

http://en.wikipedia.org/wiki/Code_smell

Let’s look at a few…

Magic Numbers

```
double potentialEnergy(double mass, double height) {
    return mass * 9.81 * height;
}
```

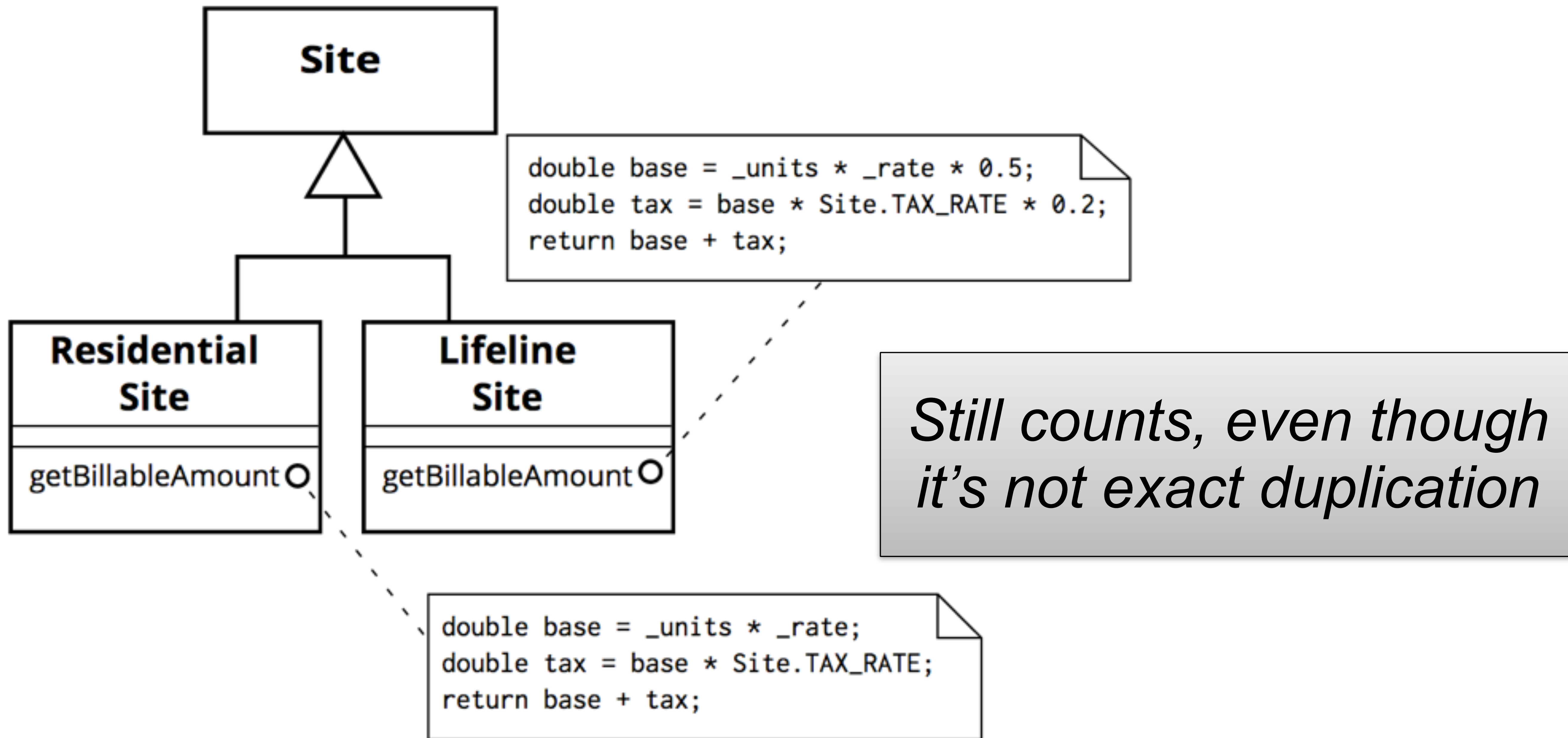
Any use of an actual number right in the code

Duplicate Code

```
extern int array1[];
extern int array2[];

int sum1 = 0;
int sum2 = 0;
int average1 = 0;
int average2 = 0;

for (int i = 0; i < 4; i++)
{
    sum1 += array1[i];
}
average1 = sum1/4;

for (int i = 0; i < 4; i++)
{
    sum2 += array2[i];
}
average2 = sum2/4;
```

These two loops are the same!

Almost-duplication



http://stackoverflow.com/a/475762

Method too long…

some red flags…

Deeply nested control structures: e.g. for-loops 3 levels deep or even just 2 levels deep with nested if-statements that have complex conditions.

Too many state-defining parameters: By state-defining parameter, I mean a function parameter that guarantees a particular execution path through the function. Get too many of these type of parameters and you have a combinatorial explosion of execution paths (this usually happens in tandem with #1).

Logic that is duplicated in other methods: poor code re-use is a huge contributor to monolithic procedural code. A lot of such logic duplication can be very subtle, but once re-factored, the end result can be a far more elegant design.

Excessive inter-class coupling: this lack of proper encapsulation results in functions being concerned with intimate characteristics of other classes, hence lengthening them.

Unnecessary overhead: Comments that point out the obvious, deeply nested classes, superfluous getters and setters for private nested class variables, and unusually long function/variable names can all create syntactic noise within related functions that will ultimately increase their length.

Your massive developer-grade display isn't big enough to display it: Actually, displays of today are big enough that a function that is anywhere close to its height is probably way too long. But, if it is larger, this is a smoking gun that something is wrong.

You can't immediately determine the function's purpose: Furthermore, once you actually do determine its purpose, if you can't summarize this purpose in a single sentence or happen to have a tremendous headache, this should be a clue.

Complicated Conditionals

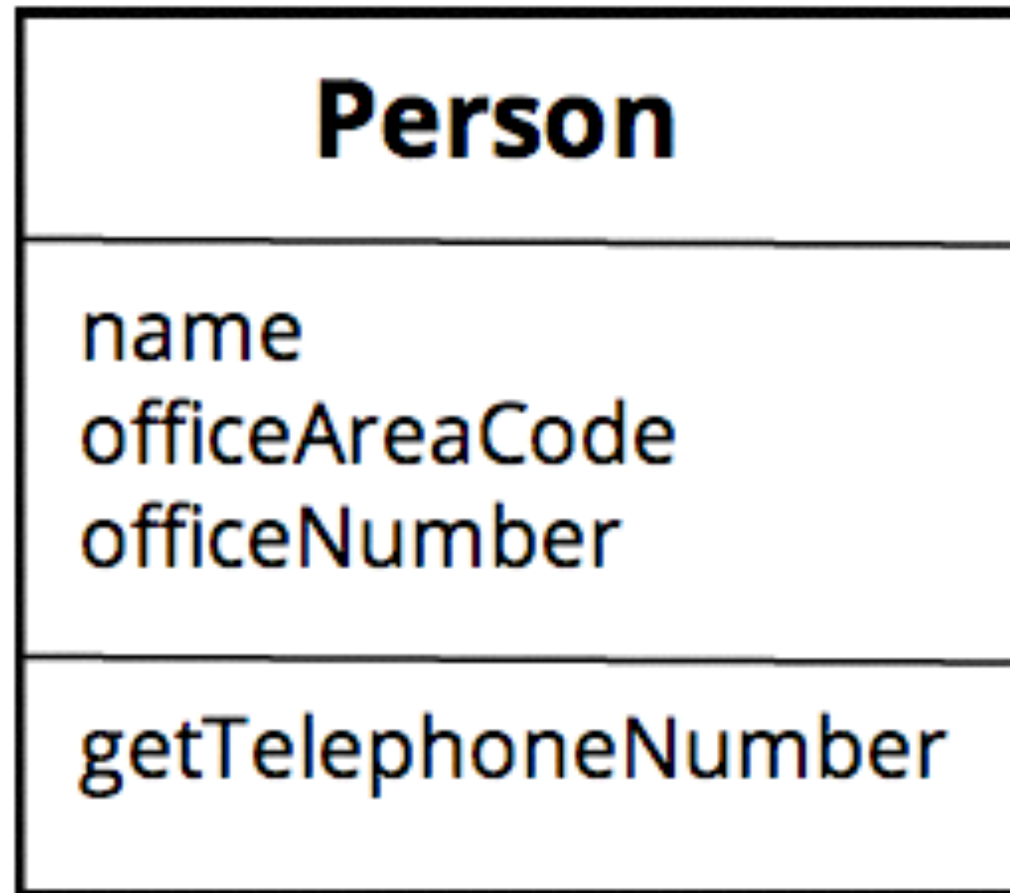
```
if (date.before (SUMMER_START) || date.after(SUMMER_END))
  charge = quantity * _winterRate + _winterServiceCharge;
else charge = quantity * _summerRate;
```

Switch Statements

a conditional that chooses different behaviour depending on the type of an object (or a weird string representation of that type)

```
double getSpeed() {
    switch (_type) {
        case EUROPEAN:
           return getBaseSpeed();
        case AFRICAN:
           return getBaseSpeed() - getLoadFactor() * _numberOfCoconuts;
        case NORWEGIAN_BLUE:
           return (_isNailed) ? 0 : getBaseSpeed(_voltage);
    }
    throw new RuntimeException ("Should be unreachable");
}
```

One class is actually two



Data Clump

always passed around together

```
public static void copyRange(int start, int end)
{
   //do something
}
```

Sometimes combined with "Long Parameter List" where bunches of data clumps are passed into a method with just too many parameters

> *A good test is to consider deleting one of the data values: if you did this, would the others make any sense?*
> *If not, you have a data clump!*

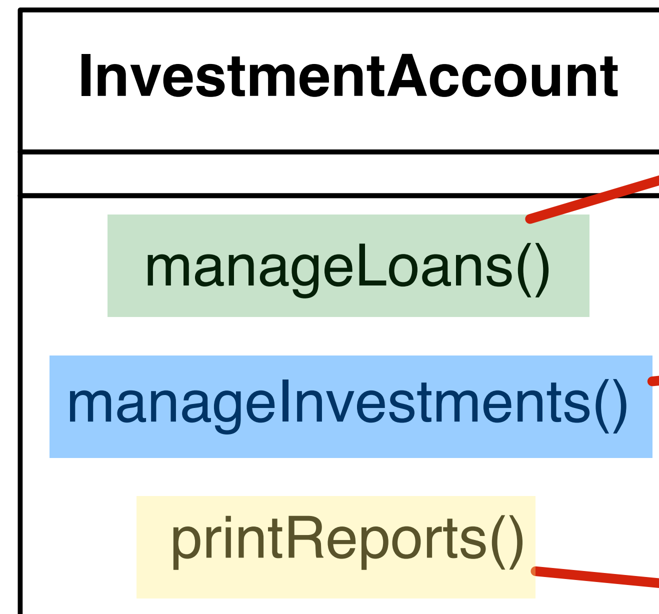
http://sourcemaking.com/refactoring/data-clumps

Divergent Changes

When you have to alter a class for more than one kind of change

Divergent change occurs when one class is commonly changed in different ways for different reasons. …
Any change to handle a variation should change a single class, and all the typing in the new class should express the variation.

3 reasons for change!



will need to change whenever the loans implementation is changed

will need to change whenever investment implementation is changed

will need to change every time the printing implementation is changed

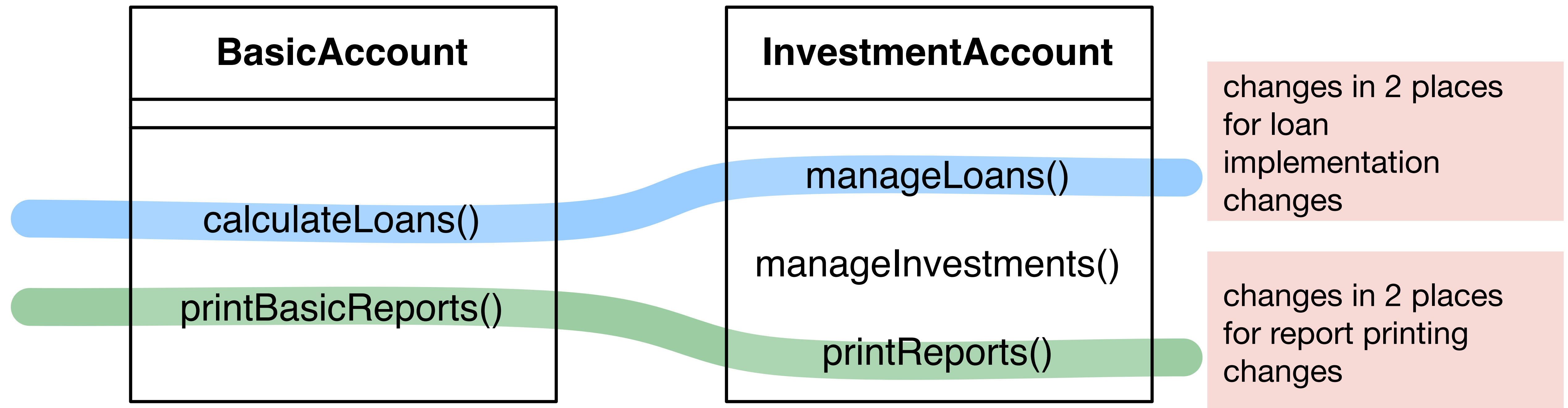
If you look at a class and say, "Well, I will have to change these three methods every time I get a new database; I have to change these four methods every time there is a new financial instrument," you likely have a situation in which two objects are better than one. That way each object is changed only as a result of one kind of change. Of course, you often discover this only after you've added a few databases or financial instruments.

A change that alters many classes

Shotgun Surgeries

You whiff this when every time you make a kind of change, you have to make a lot of little changes to a lot of different classes. When the changes are all over the place, they are hard to find, and it's easy to miss an important change.

this is the inverse of divergent change. One change in lots of places, versus one place with lots of changes



http://sourcemaking.com/refactoring/shotgun-surgery

this isn't the same as the REQUIRES/MODIFIES/EFFECTS comments we used in 210!

Needing comments to explain the code

… comments often are used as a deodorant. It's surprising how often you look at thickly commented code and notice that the comments are there because the code is bad.

A good time to use a comment is when you don't know what to do. In addition to describing what is going on, comments can indicate areas in which you aren't sure. A comment is a good place to say why you did something. This kind of information helps future modifiers, especially forgetful ones.

```
# convert to cents
a = x * 100

# avg cents per customer
avg = a / n

# add to list
avgs < avg
t += 1
```

```
double getExpenseLimit() {
       // should have either expense limit or a primary project
       return (_expenseLimit != NULL_EXPENSE) ?
           _expenseLimit:
           _primaryProject.getMemberExpenseLimit();
   }
```

Okay…

- So now we know some symptoms of bad code.
- What do you do in response?

REFACTOR!

- Long-term investment in the quality of the code and its structure
- No refactoring may save costs / time in the short term but incurs a huge penalty in the long run

What is “Refactoring”

“[Refactoring is] the process of changing a software system in such a way that it does not alter the external behavior of the code yet improves its internal structure” – Martin Fowler

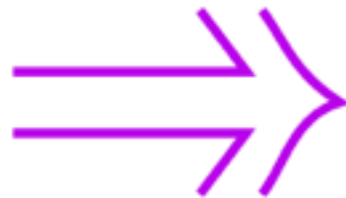
- Changes made to a system that:
    - **Do not** change observable behavior
        - (MEANING PRESERVING)
    - Remove duplication or needless complexity
    - Enhance software quality
    - Make the code easier and simpler to understand
    - Make the code more flexible
    - Make the code easier to change
- Requires Tests!

Refactoring

- At its simplest, it's just a small, behaviour-preserving, source-to-source transformation.

- Example:

```
extern int array1[];
extern int array2[];

int sum1 = 0;
int sum2 = 0;
int average1 = 0;
int average2 = 0;

for (int i = 0; i < 4; i++)
{
   sum1 += array1[i];
}
average1 = sum1/4;

for (int i = 0; i < 4; i++)
{
   sum2 += array2[i];
}
average2 = sum2/4;
```



```
int calcAverage (int* Array_of_4)
{
    int sum = 0;
    for (int i = 0; i < 4; i++)
    {
        sum += Array_of_4[i];
    }
    return sum/4;
}
```

Definition of broken code:

Every module has three functions:

- To execute according to its purpose
- To afford change
- To communicate to its readers
- If it does not do one or more of these, it is broken.

```
q = ((p<=1) ? (p ? 0 : 1) : (p==-4) ? 2 : (p
   +1));

while (*a++ = *b--) ;

char b[2][10000],*s,*t=b,*d,*e=b+1,**p;main(int
   c,char**v){int n=atoi(v[1]); strcpy(b,v[2]);
   while(n--){for(s=t,d=e;*s; s++)    {for(p=v
   +3;*p;p++) if(**p==*s){strcpy(d,*p+2);d+=
   strlen(d);goto x;}*d++=*s;x:} s=t;t=e;e=s; *d
   ++=0;}puts(t);}
```

When **to** refactor?

- NOT: 2 weeks every 6 months
- Do it as you develop - Opportunistic Refactoring
- Boy Scout principle: leave it better than you found it.
- If you recognize a warning sign (a bad smell)
  - When you add a function
    - Before, to start clean   and/or
    - After, to clean-up
  - When you fix a bug
  - When you code review
  - You can use The Rule of Three

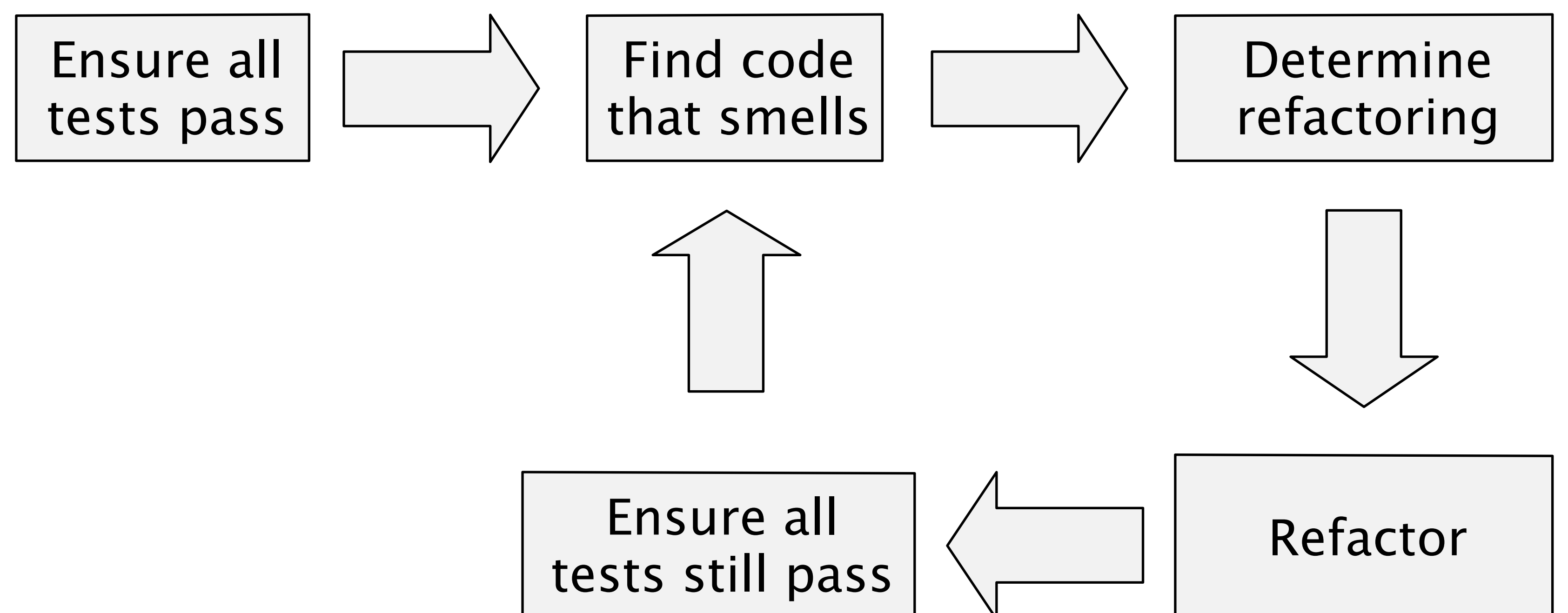
1. The first time, just do it!
2. Need it somewhere else? Cut and paste it!
3. The third time, refactor!

When **not to** refactor?

- When the tests are failing
- When you should just rewrite the code
- When you have impending deadlines

How to refactor?

1. Make sure all your tests pass
2. Identify the code smell
3. Determine how to refactor this code
4. Apply the refactoring
5. Run tests to make sure you didn't break anything
6. Repeat until the smell is gone



Refactorings fix Code Smells

- Add Parameter
- Change Bidirectional Association to Unidirectional
- Change Reference to Value
- Change Unidirectional Association to Bidirectional
- Change Value to Reference
- Collapse Hierarchy
- Consolidate Conditional Expression
- Consolidate Duplicate Conditional Fragments
- Convert Procedural Design to Objects
- Decompose Conditional
- Duplicate Observed Data

Each of these is one predictably meaning preserving code transformation.

- Encapsulate Collection
- Encapsulate Downcast
- Encapsulate Field
- Extract Class
- Extract Hierarchy
- Extract Interface
- Extract Method
- Extract Subclass
- Extract Superclass
- Form Template Method
- Hide Delegate
- Hide Method
- Inline Class
- Inline Method
- Rename Constant

Online: http://www.refactoring.com/catalog

smell: magic numbers
refactoring: replace it with a symbolic constant

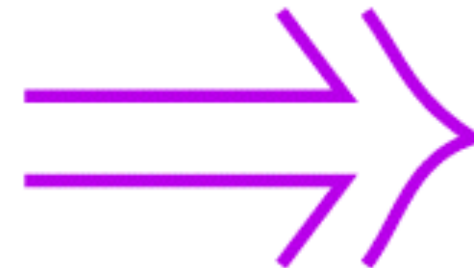
```
double potentialEnergy(double mass, double height) {
    return mass * 9.81 * height;
}
```

```
double potentialEnergy(double mass, double height) {
    return mass * GRAVITATIONAL_CONSTANT * height;
}
static final double GRAVITATIONAL_CONSTANT = 9.81;
```

Smell: Repeated Lines of Code
Refactoring: Extract Method

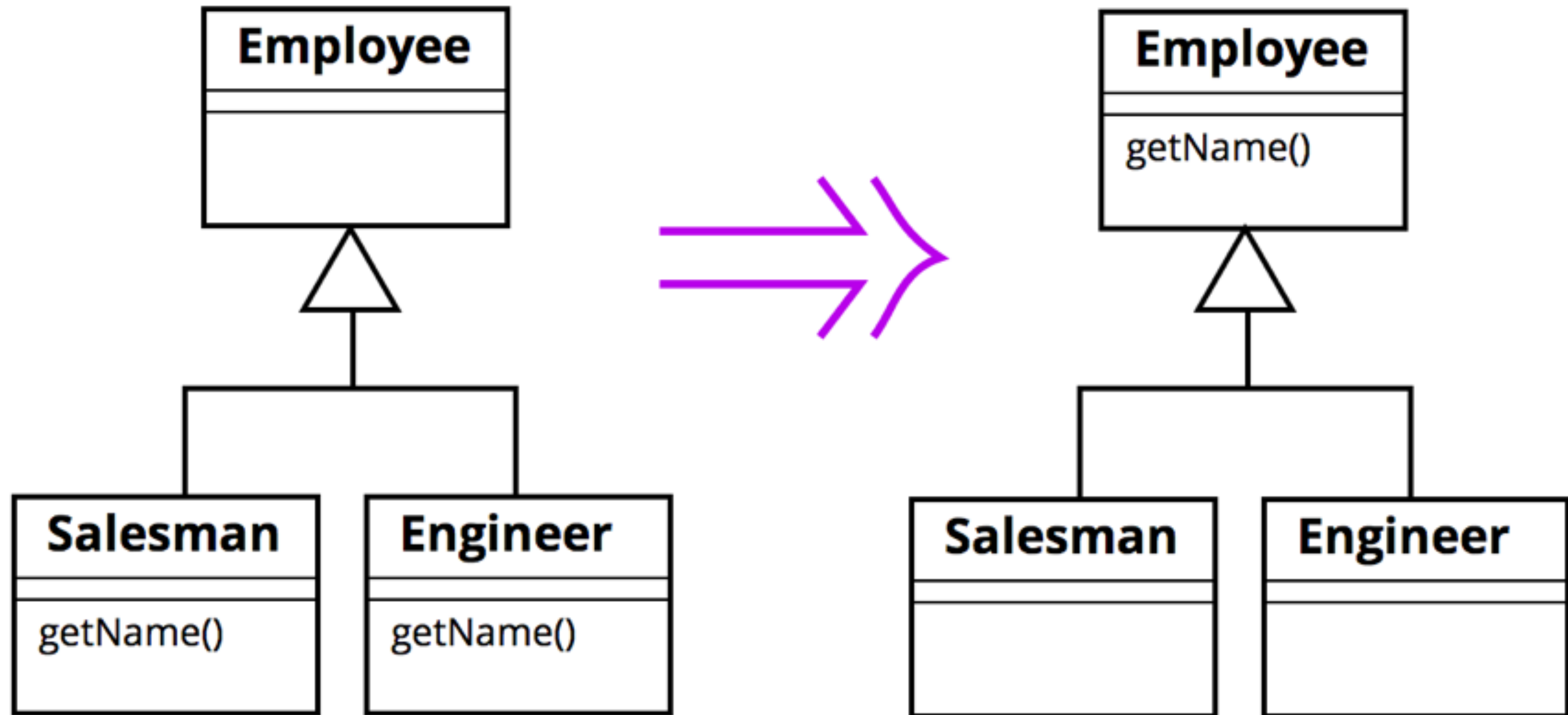
Not all duplicate code gets fixed by extracting a method. You need to carefully assess what kind of duplication you have.

```
void printOwing() {
  printBanner();

  //print details
  System.out.println ("name:   " + _name);
  System.out.println ("amount " + getOutstanding());
}
```



```
void printOwing() {
  printBanner();
  printDetails(getOutstanding());
}

void printDetails (double outstanding) {
  System.out.println ("name:   " + _name);
  System.out.println ("amount " + outstanding);
}
```

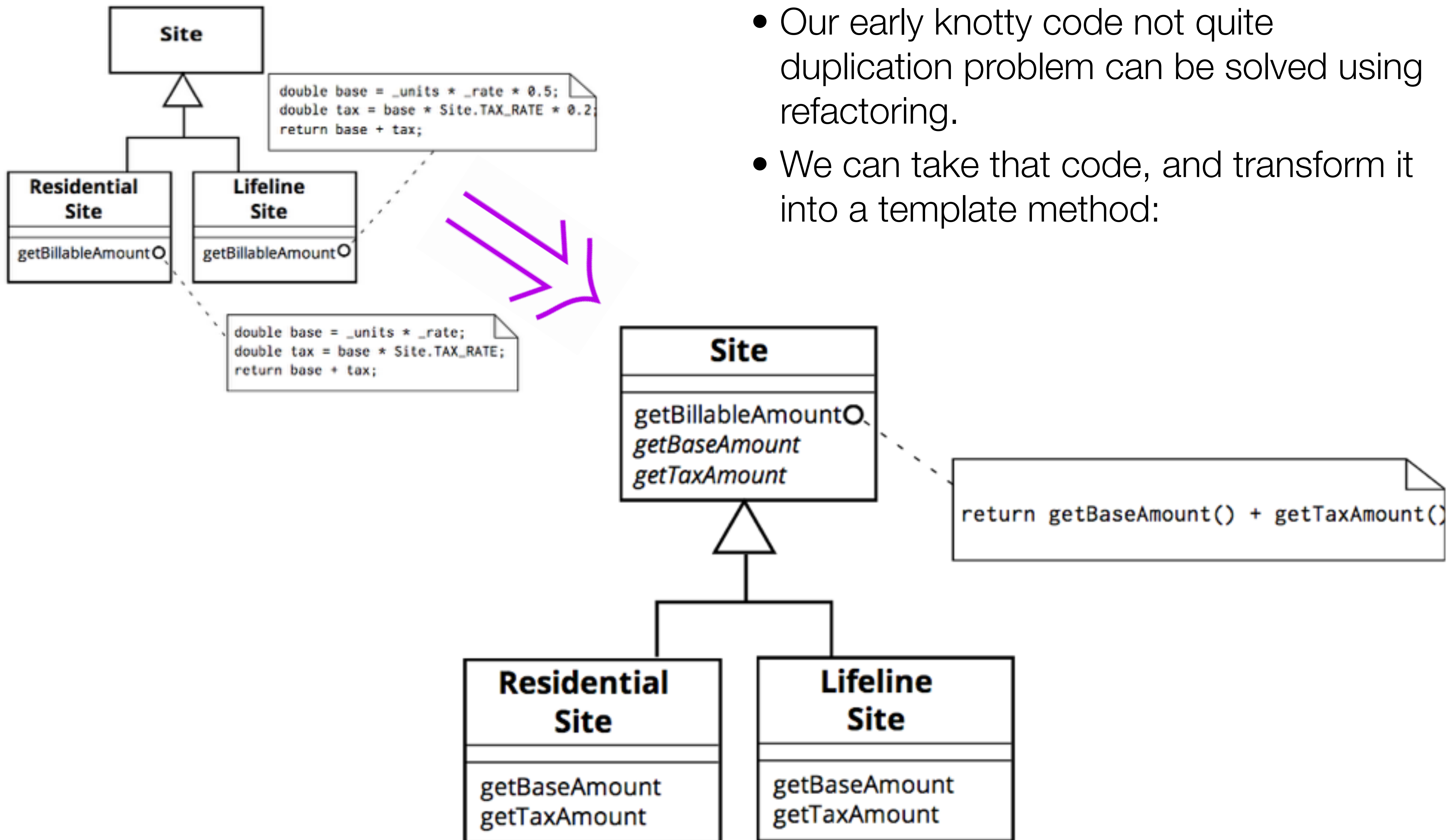
Smell: same method in two classes
Refactoring: Pull up method



http://www.refactoring.com/catalog/pullUpMethod.html

Smell: almost duplicated code
Refactoring: move to template method

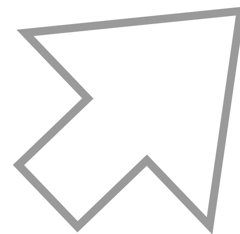
- Our early knotty code not quite duplication problem can be solved using refactoring.
- We can take that code, and transform it into a template method:



Smell: Long method
Refactoring(s): Lots of options!

Extract Method*:*

- *Pull code out into a separate method when the original method is long or complex*
- *Name the new method so as to make the original method clearer*
- *Each method should have just one task*



- Extract Method
- Replace Temp with Query
- Replace Method with Method Object
- Decompose Conditional
- Consolidate Conditional Expression

smell: Complicated conditional
Refactoring: Decompose conditional

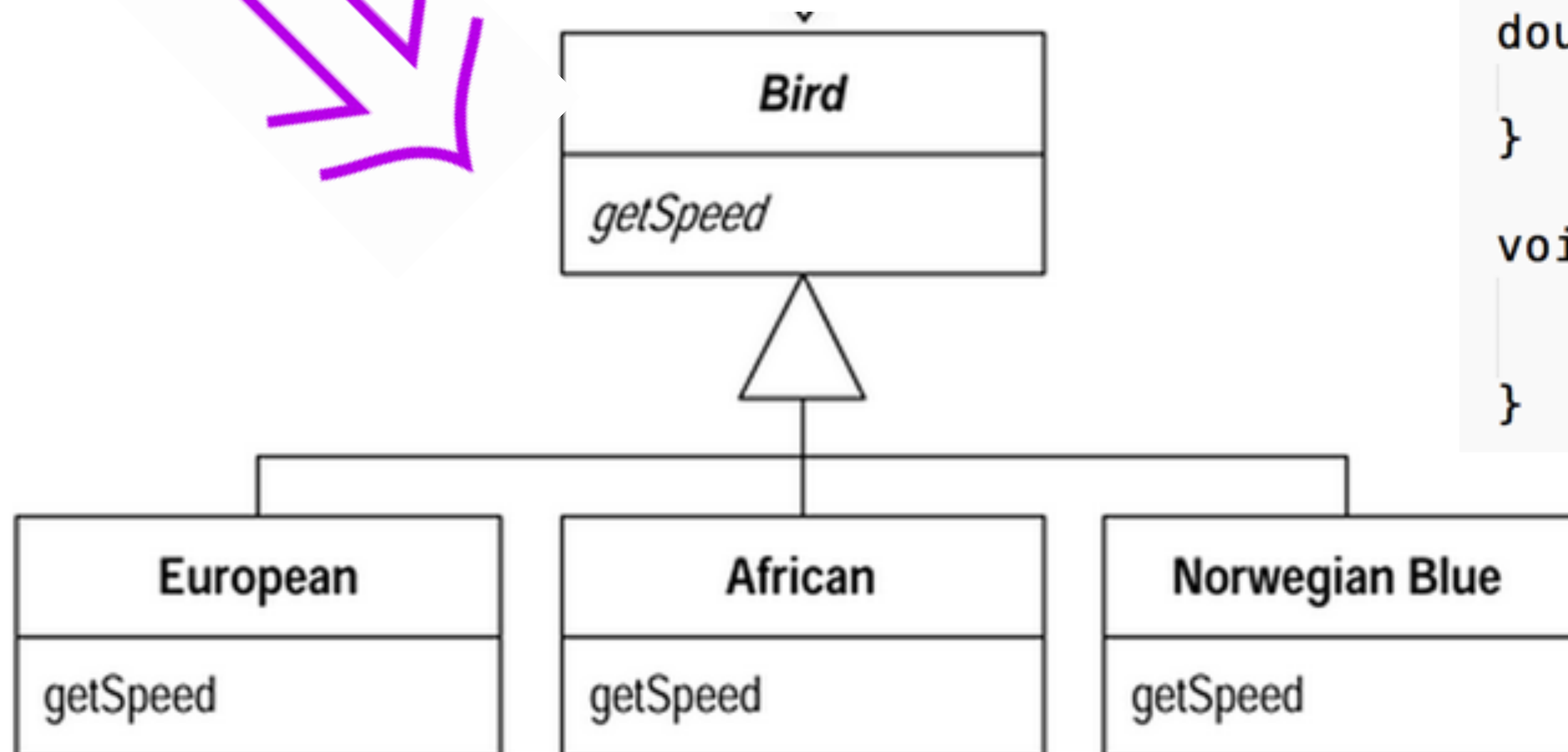
```
if (date.before (SUMMER_START) || date.after(SUMMER_END))
  charge = quantity * _winterRate + _winterServiceCharge;
else charge = quantity * _summerRate;
```

extract methods from the condition, the "then" and the "else" parts.

```
if (notSummer(date))
  charge = winterCharge(quantity);
else charge = summerCharge (quantity);
```

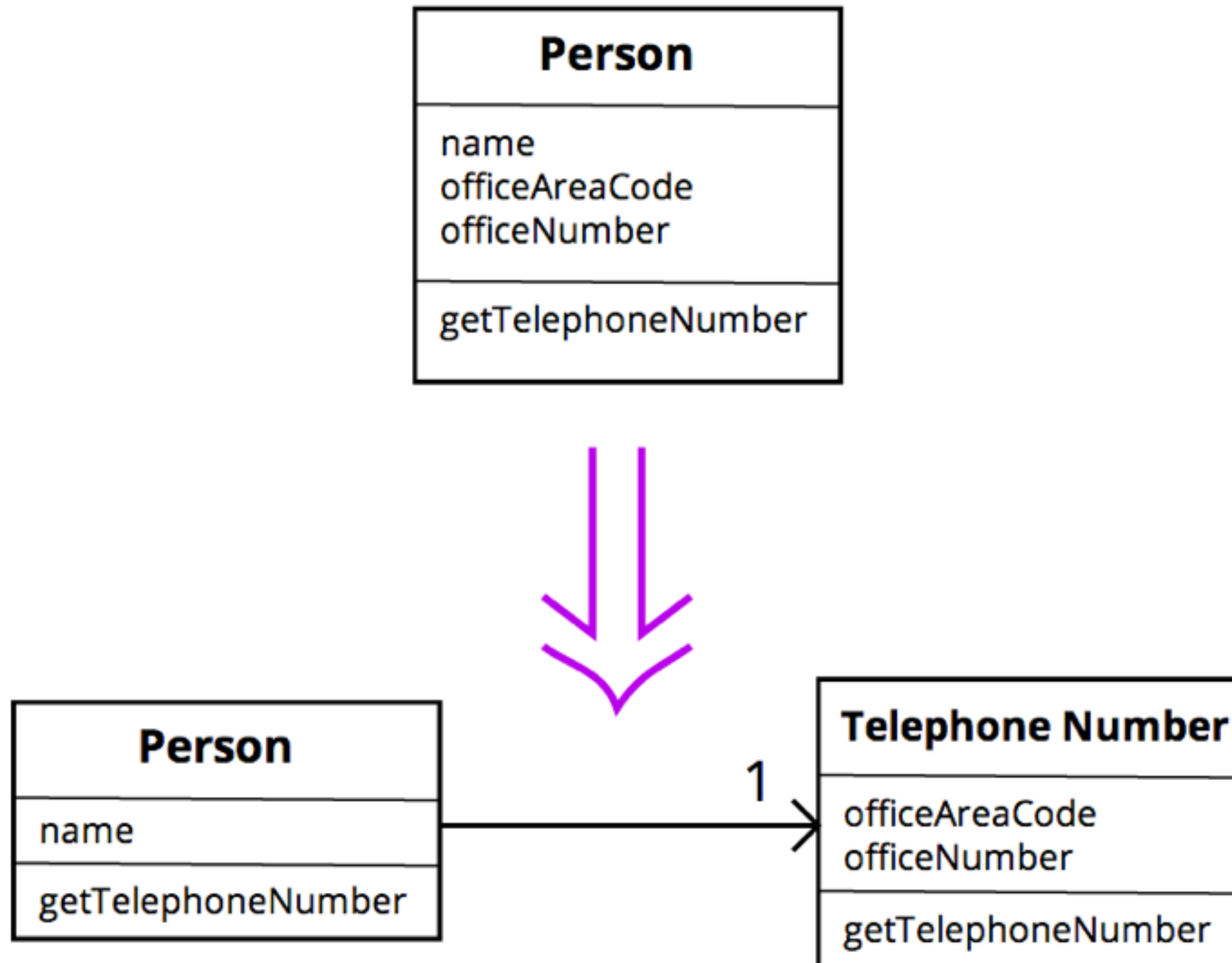
smell: switch statement/typed conditional
refactor: replace conditional with polymorphism

```
double getSpeed() {
    switch (_type) {
        case EUROPEAN:
           return getBaseSpeed();
        case AFRICAN:
           return getBaseSpeed() - getLoadFactor() * _numberOfCoconuts;
        case NORWEGIAN_BLUE:
           return (_isNailed) ? 0 : getBaseSpeed(_voltage);
    }
    throw new RuntimeException ("Should be unreachable");
}
```



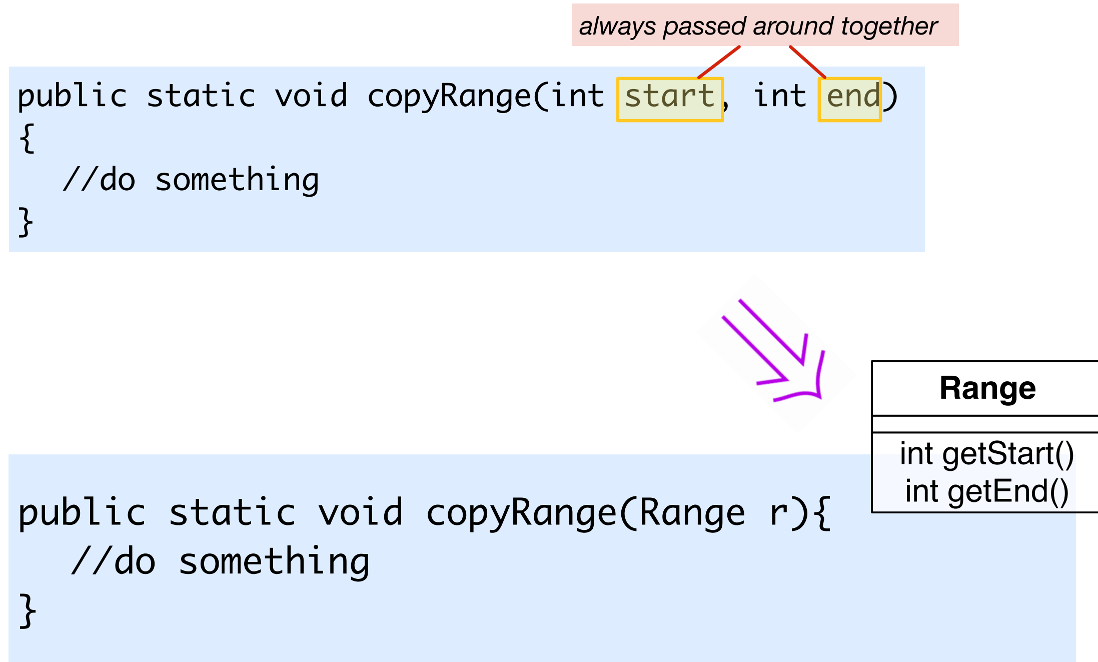

```
double getSpeed(Bird bird) {
    bird.getSpeed();
}

void main (){
    Bird b = new African();
    getSpeed(b);
}
```

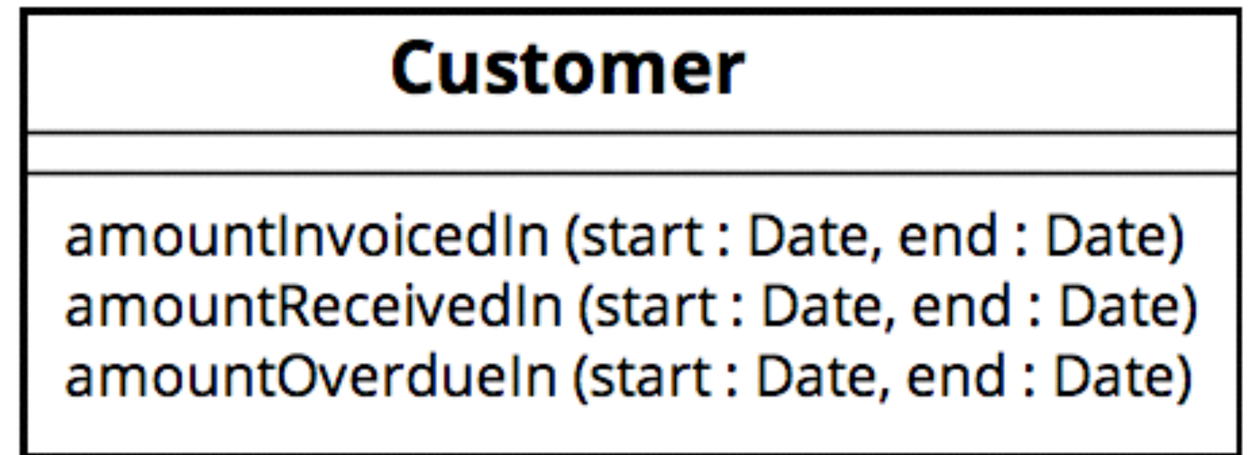
Smell: one class doing the work of two
Refactoring: extract class

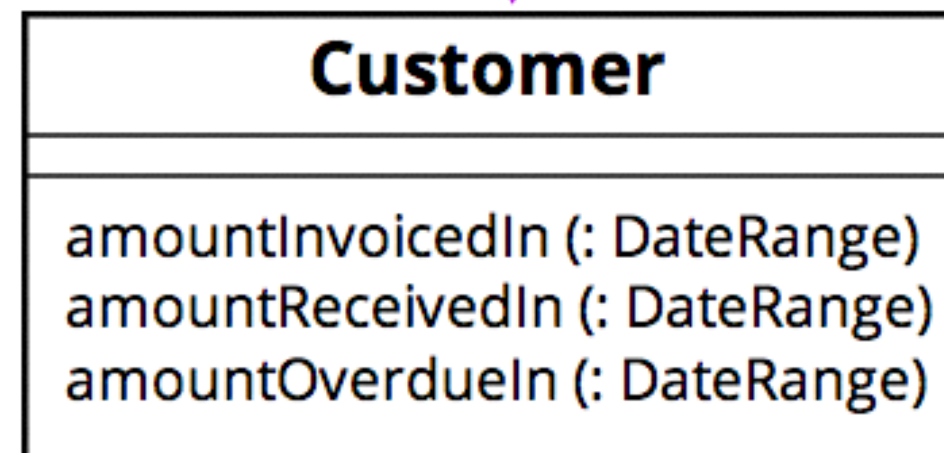


Smell: data clump (parameters that always go together)
Refactoring: introduce parameter object

Introduce parameter object - If you have a group of parameters that naturally go together then you can replace them with an object.





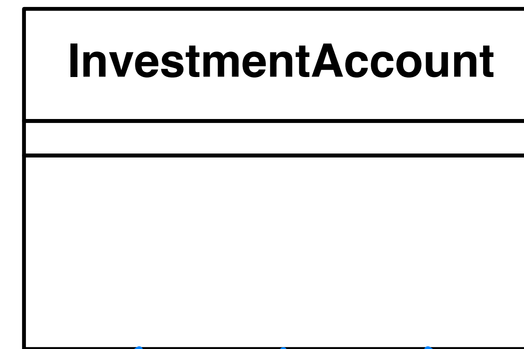


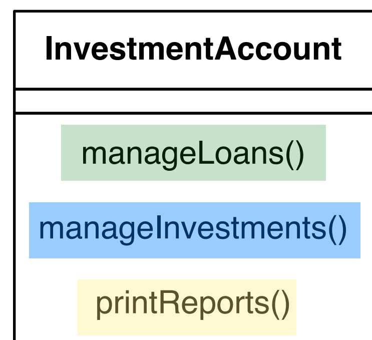
http://martinfowler.com/bliki/DataClump.html

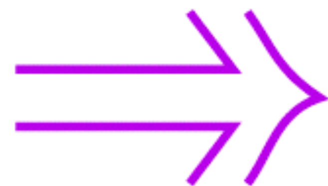
smell: divergent changes
refactoring: extract class

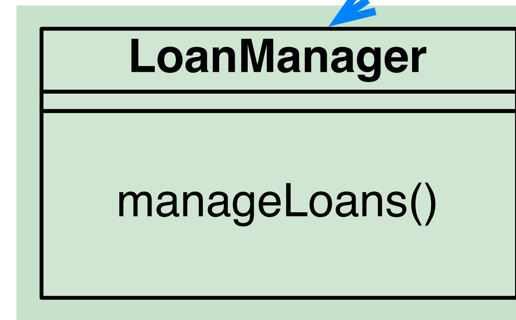
ideally, there is a one-to-one link between common changes and classes.

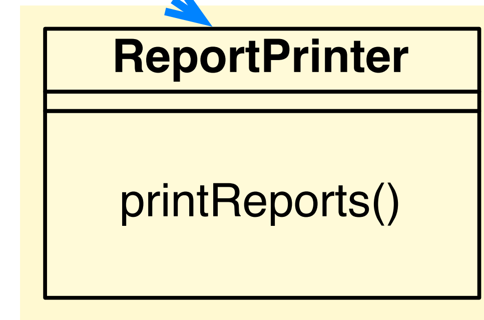
identify everything that changes for a particular cause and use Extract Class to put them all together











will need to change whenever the loans implementation is changed

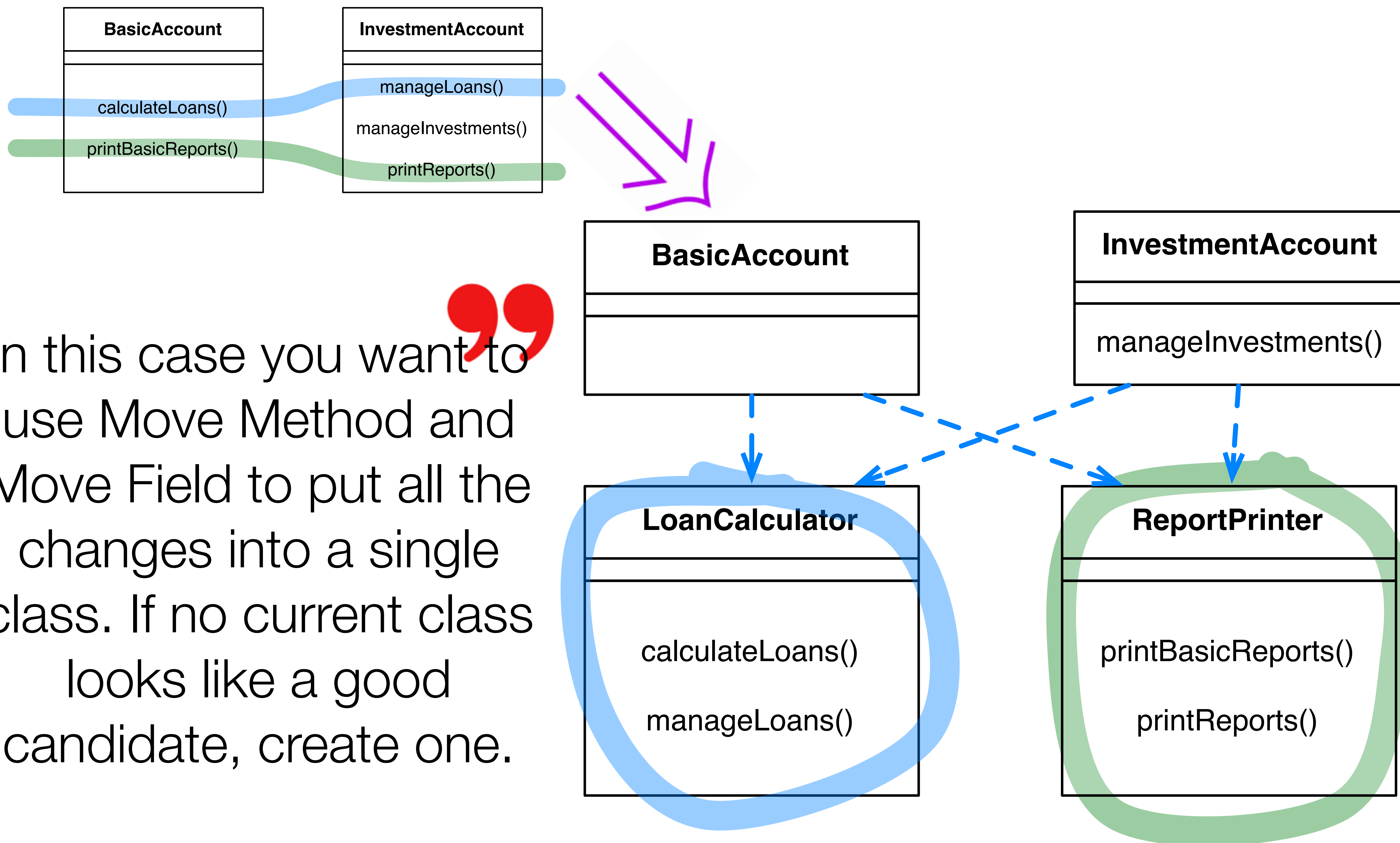
will need to change whenever investment implementation is changed

will need to change every time the printing implementation is changed

https://www.youtube.com/watch?v=f2-6W8wxIj0

smell: shotgun surgery
refactoring: move method; move field

ideally, there is a one-to-one link between common changes and classes.



In this case you want to use Move Method and Move Field to put all the changes into a single class. If no current class looks like a good candidate, create one.

smell: needing comments to explain the code
refactoring: extract functionality/introduce assertion

When you feel the need to write a comment, first try to refactor the code so that any comment becomes superfluous

```
double getExpenseLimit() {
      // should have either expense limit or a primary project
      return (_expenseLimit != NULL_EXPENSE) ?
          _expenseLimit:
          _primaryProject.getMemberExpenseLimit();
  }
```

```
double getExpenseLimit() {
    Assert.isTrue (_expenseLimit != NULL_EXPENSE || _primaryProject != null);
    return (_expenseLimit != NULL_EXPENSE) ?
        _expenseLimit:
        _primaryProject.getMemberExpenseLimit();
}
```

```
# convert to cents
a = x * 100

# avg cents per customer
avg = a / n

# add to list
avgs < avg
t += 1
```

```
total_cents = total * 100
average_per_customer = total_cents / customer_count

track_average(average_per_customer)
```

http://programmers.stackexchange.com/questions/1/comments-are-a-code-smell

Now … with all that under our belts…

What smells?

```
class Account {
  float principal, rate;
  int daysActive, accountType;

  public static final int STANDARD = 0;
  public static final int BUDGET = 1;
  public static final int PREMIUM = 2;
  public static final int PREMIUM_PLUS = 3;
}

class Customer {
  public float calculateFee(Account accounts[]) {
    float totalFee = 0;
    Account account;
    for (int i=0; i<accounts length; i++)
    if ( account.accountType == Account.PREMIUM ||
         account.accountType == Account.PREMIUM_PLUS ) {
         totalFee += .0125 * ( account.principal
                          * Math.exp( account.rate * (account.daysActive/365.25) )
                          - account.principal );
    }
    return totalFee;
  }
}
```

What smells?

```
class Account {
  float principal, rate;
  int daysActive, accountType;

  public static final int STANDARD = 0;
  public static final int BUDGET = 1;
  public static final int PREMIUM = 2;
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class Customer {
  public float calculateFee(Account accounts[]) {
    float totalFee = 0;
    Account account;
    for (int i=0; i<accounts length; i++)
    if ( account.accountType == Account.PREMIUM ||
         account.accountType == Account.PREMIUM_PLUS ) {
         totalFee += .0125 * ( account.principal
                         * Math.exp( account.rate * (account.daysActive/365.25) )
                         - account.principal );
    }
    return totalFee;
  }
}
```

Complicated Conditional

Magic Number

unreadable functionality

Which refactorings would work?

```
class Account {
  float principal, rate;
  int daysActive, accountType;

  public static final int STANDARD = 0;
  public static final int BUDGET = 1;
  public static final int PREMIUM = 2;
  public static final int PREMIUM_PLUS = 3;
}

class Customer {
  public float calculateFee(Account accounts[]) {
    float totalFee = 0;
    Account account;
    for (int i=0; i<accounts length; i++)
    if ( account.accountType == Account.PREMIUM ||
         account.accountType == Account.PREMIUM_PLUS ) {
         totalFee += .0125 * ( account.principal
                          * Math.exp( account.rate * (account.daysActive/365.25) )
                          - account.principal );
    }
    return totalFee;
  }
}
```

Decompose Conditional

Complicated Conditional

Replace with Symbolic Constant

Magic Number

unreadable functionality

Extract Functionality

The end result. . .

```
class Account {
  float principal, rate;
  int daysActive, accountType;

  public static final int STANDARD = 0;
  public static final int BUDGET = 1;
  public static final int PREMIUM = 2;
  public static final int PREMIUM_PLUS = 3;
}

class Customer {
  public float calculateFee(Account accounts[]) {
    float totalFee = 0;
    Account account;
    for (int i=0; i<accounts length; i++)
    if ( account.accountType == Account.PREMIUM ||
         account.accountType == Account.PREMIUM_PLUS ) {
         totalFee += .0125 * ( account.principal
                       * Math.exp( account.rate * (account.daysActive/365.25) )
                       - account.principal );
    }
    return totalFee;
  }
}
```

Decompose Conditional

Complicated Conditional

Replace with Symbolic Constant

Magic Number

unreadable functionality

Extract Functionality

```
private float interestEarned() {
  float years = daysActive / (float) 365.25;
  float compoundInterest = principal * (float) Math.exp( rate * years );
  return ( compoundInterest – principal );
}

private float isPremium() {
  if (accountType == Account.PREMIUM || accountType == Account.PREMIUM_PLUS)
    return true;
  else return false;
}

public float calculateFee(Account accounts[]) {
  float totalFee = 0;
  Account account;
  for (int i=0; i<accounts.length; i++) {
    account = accounts[i];
    if ( account isPremium() )
      totalFee += BROKER_FEE_PERCENT * account.interestEarned();
  }
  return totalFee;;
}

static final double BROKER_FEE_PERCENT = 0.0125;
```

Extract Functionality

Decompose Conditional

Replace with Symbolic Constant

Resources

- “The” Book, by Martin Fowler
  - Refactoring: Improving the design of existing code
- Smells to refactorings
  - http://wiki.java.net/bin/view/People/SmellsToRefactorings
- List of refactorings
  - http://www.refactoring.com/catalog
- A refactoring “cheat sheet”
  - http://industriallogic.com/papers/smellstorefactorings.pdf
- Use IDE support! Manual refactoring is hard and potentially error prone. Eclipse/IntelliJ both provide automatic refactoring support)

Remember:

- A potential for refactoring is not a smell
  - Just because you see a potential for refactoring doesn't mean you should apply it. Only refactor if the code suffers from a code smell.
  - Some refactorings are opposites of one another (you could get caught in a loop of refactorings if you do them just for the sake of it! Inline versus Extract method, for instance.)
- First smell, then refactor

Summary

- Code decays for many reasons
  - Collaboration, rework, external conditions, agility
- Refactoring improves existing code
  - Does not change existing behaviour
- Refactoring improves maintainability and hence productivity
- Refactor continuously
- Refactoring is an iterative process
  - Tests pass → Find smell → Refactor → Repeat
- Many smells, even more refactorings!