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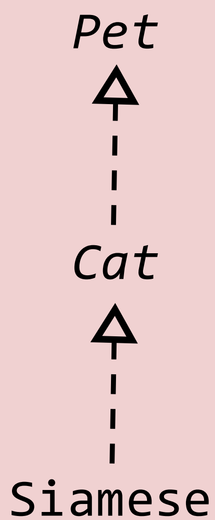
PollEv.com/javabear text **javabear** to 22333

Suppose that `Cat <: Pet` and `Siamese <: Cat`. What will happen if we try to compile and run the bottom code snippet?




```
interface Pet { ... }

interface Cat extends Pet { ... }

class Siamese implements Cat { ... }
```

```
1. Siamese s = new Siamese();
2. Cat c = new Siamese();
3. Pet p = c;
4. s = c;
```

- Compiler error (Line 2) **(A)**
- Compiler error (Line 3) **(B)**
- Compiler error (Line 4) **(C)**
- Runs without error **(D)**

Reminders

- A4 due Wednesday
- Prelim 1 in ~ 2.5 weeks
  - Fill out conflict form if necessary (pinned on Ed)
  - More exam info (+ practice exam) coming in ~ 1 week
- TA midterm evaluations later this week (see email)
- Take advantage of support resources (Ed, office hours, assignment resubmissions, etc.)

Reference Type Coercion

Sometimes, the CTRR gets in the way, and we need to adjust the compiler's view to access a behavior

```
Account savings = new SavingsAccount("Savings", 230000, 3.0);
System.out.println(((SavingsAccount) savings).interestRate() + "%");
```

We can use casting to adjust the compiler's view (lower in type hierarchy)

Compile Time: Compiler "trusts cast" if it can possibly succeed

Runtime: Dynamic type determines if cast actually works (or if exception is thrown)

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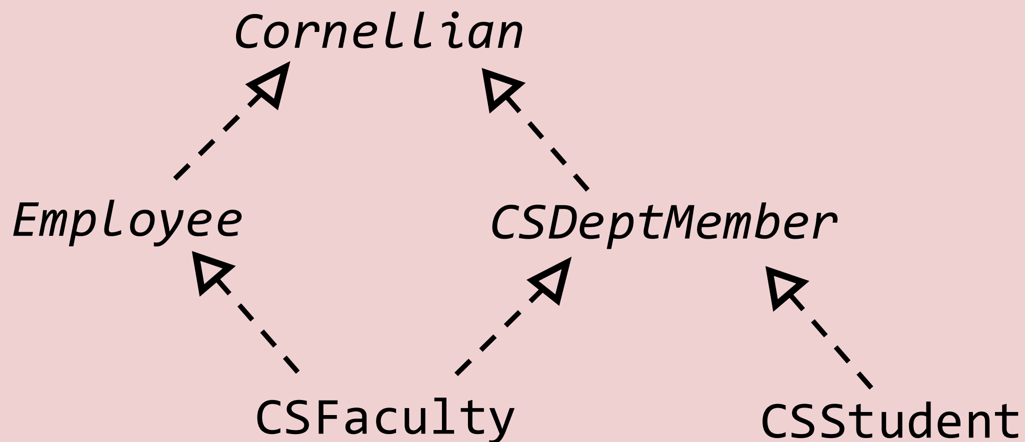
Given the following type hierarchy and variable declarations, which cast will ***not*** compile?



Cornellian c; Employee e; CSFaculty f;
CSStudent s; CSDeptMember d;

upcast: not needed, but ok

```
d = (CSDeptMember) s;
```
(A)

works if c → CSFaculty

```
f = (CSFaculty) c;
```
(B)

works if d → CSFaculty

```
e = (Employee) d;
```
(C)

no, student can't be Faculty

```
f = (CSFaculty) s;
```
(D)

Lecture 10: Inheritance

CS 2110

February 24, 2026

Today's Learning Outcomes

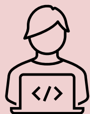
43. Describe the principle of dynamic dispatch and the compile-time reference rule.

44. Explain inheritance relationships and their benefits/drawbacks over interfaces.

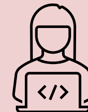
45. Given a parent class, use inheritance to develop one or more child subclasses.

46. Determine the correct visibility modifier (public, protected, or private) for a given field or method and justify your choice.

47. Trace through the execution of a code sample that includes one or more of the following: inheritance, overridden methods, and super calls



Coding Demo: Our Account Classes



New for today: Checking Accounts may have monthly fee if balance drops too low.

Repetitive "Code Smell"

CheckingAccount

```java
/** Models a checking account in our personal finance app. */
public class CheckingAccount implements Account {
  /**
   * The balance must remain above this amount, in cents, to prevent
   * the monthly account fee.
   */
  public static final int MINIMUM_BALANCE = 10000;

  /** The monthly account fee. */
  public static final int ACCOUNT_FEE = 500;

  /** The name of this account. */
  private String name;

  /** The current balance, in cents, of this account. */
  private int balance;

  /** The current month's transaction report */
  private StringBuilder transactions;

  /** Whether the account fee should be charged this month. */
  private boolean chargeFee;

  /**
   * Constructs a checking account with given `name` and initial `balance`.
   */
  public CheckingAccount(String name, int balance) {
    this.name = name;
    this.balance = balance;
    resetTransactionLog();
  }

  /**
   * Reassigns the transaction log to a new `StringBuilder` object that
   * contains this month's initial account balance, and resets `chargeFee`.
   */
  private void resetTransactionLog(){
    this.chargeFee = this.balance < MINIMUM_BALANCE;
    this.transactions = new StringBuilder("Initial Balance:");
    this.transactions.append(centsToString(this.balance));
    this.transactions.append("\n"); // newline
  }

  /**
   * Converts the given number of `cents` into a String in "$X.XX" format.
   */
  private static String centsToString(int cents){
    int dollars = cents / 100;
    cents = cents % 100;
    return ("$" + dollars + "." + (cents < 10 ? "0" : "") + cents);
  }

  @Override
  public String name() {
    return this.name;
  }

  @Override
  public int balance() {
    return this.balance;
  }

  /**
   * Deposits the specified `amount`, in cents, to the balance of the
   * account, logs this transaction with the given `memo`, and returns
   * `true` to indicate that this deposit was successful. Requires that
   * `amount > 0`.
   */
  @Override
  public boolean depositFunds(int amount, String memo) {
    assert amount > 0;
    this.balance += amount;
    this.transactions.append(" - Deposit ");
    this.transactions.append(centsToString(amount));
    this.transactions.append(":");
    this.transactions.append(memo);
    this.transactions.append("\n");
    return true; // we can always add funds to a checking account
  }

  /**
   * Attempts to transfer the specified `amount`, in cents, from this account
   * to `receivingAccount` and returns whether this transaction was successful.
   * If this transaction is successful, it is logged to both accounts with the
   * given `memo`. Otherwise, no changes are made to either account and no
   * transaction is logged. Updates `chargeFee` if `balance` drops below
   * `MINIMUM_BALANCE`. Requires that `amount > 0`.
   */
  @Override
  public boolean transferFunds(Account receivingAccount, int amount) {
    assert amount > 0;
    if (amount > this.balance) {
      return false; // insufficient funds
    }
    if (!receivingAccount.depositFunds(amount, "Transfer from " + this.name)){
      return false; // could not add funds
    }
    this.balance -= amount;
    this.chargeFee |= this.balance < MINIMUM_BALANCE;
    this.transactions.append(" - Transfer ");
    this.transactions.append(centsToString(amount));
    this.transactions.append(" to ");
    this.transactions.append(receivingAccount.name());
    this.transactions.append("\n");
    return true;
  }

  /**
   * Called once at the end of each month to return a `String` summarizing the
   * account's initial balance that month, all transactions made during that
   * month, and its final balance. As a final transaction for the month, a
   * maintenance fee is applied to the account if the balance was ever below
   * `MINIMUM_BALANCE` during the month.
   */
  @Override
  public String transactionReport(){
    this.processMonthlyFee();
    this.transactions.append("Final Balance: ");
    this.transactions.append(centsToString(this.balance));
    this.transactions.append("\n");

    String report = this.transactions.toString();
    resetTransactionLog();
    return report;
  }

  /**
   * Debits the monthly account fee if the balance fell below the
   * minimum during the month.
   */
  private void processMonthlyFee(){
    if (this.chargeFee) {
      this.balance -= ACCOUNT_FEE;
      this.transactions.append(" - Withdraw ");
      this.transactions.append(centsToString(ACCOUNT_FEE));
      this.transactions.append(": Account Maintenance Fee");
      this.transactions.append("\n");
    }
  }
}
```

SavingsAccount

```java
/** Models a savings account in our personal finance app. */
public class SavingsAccount implements Account {

  /** The name of this account. */
  private String name;

  /** The current balance, in cents, of this account. */
  private int balance;

  /** The current (nominal) APR of this account. */
  private double rate;

  /** The current month's transaction report */
  private StringBuilder transactions;

  /**
   * Constructs a savings account with given `name`, initial `balance`, and interest `rate`.
   */
  public SavingsAccount(String name, int balance, double rate){
    this.name = name;
    this.balance = balance;
    this.rate = rate;
    this.resetTransactionLog();
  }

  /**
   * Reassigns the transaction log to a new `StringBuilder` object that contains this month's
   * initial account balance
   */
  private void resetTransactionLog(){
    this.transactions = new StringBuilder("Initial Balance:");
    this.transactions.append(centsToString(this.balance));
    this.transactions.append("\n"); // newline
  }

  /**
   * Converts the given number of `cents` into a String in "$X.XX" format.
   */
  private static String centsToString(int cents){
    int dollars = cents / 100;
    cents = cents % 100;
    return ("$" + dollars + "." + (cents < 10 ? "0" : "") + cents);
  }

  @Override
  public String name() {
    return this.name;
  }

  @Override
  public int balance() {
    return this.balance;
  }

  /**
   * Returns the current (nominal) APR of this account.
   */
  public double interestRate(){
    return this.rate;
  }

  /**
   * Deposits the specified `amount`, in cents, to the balance of the account,
   * logs this transaction with the given `memo`, and returns `true` to indicate
   * that this deposit was successful. Requires that `amount > 0`.
   */
  @Override
  public boolean depositFunds(int amount, String memo) {
    assert amount > 0;
    this.balance += amount;
    this.transactions.append(" - Deposit ");
    this.transactions.append(centsToString(amount));
    this.transactions.append(":");
    this.transactions.append(memo);
    this.transactions.append("\n");
    return true; // we can always add funds to a savings account
  }

  @Override
  public boolean transferFunds(Account receivingAccount, int amount) {
    assert amount > 0;
    if (amount > this.balance) {
      return false; // insufficient funds
    }
    if (!receivingAccount.depositFunds(amount, "Transfer from " + this.name)){
      return false; // could not add funds
    }
    this.balance -= amount;
    this.transactions.append(" - Transfer ");
    this.transactions.append(centsToString(amount));
    this.transactions.append(" to ");
    this.transactions.append(receivingAccount.name());
    this.transactions.append("\n");
    return true;
  }

  /**
   * Called once at the end of each month to return a `String` summarizing the
   * account's initial balance that month, all transactions made during that
   * month, and its final balance. As a final transaction for the month,
   * interest is accrued to the account based on the current `rate`.
   */
  @Override
  public String transactionReport(){
    this.accrueMonthlyInterest();
    this.transactions.append("Final Balance: ");
    this.transactions.append(centsToString(this.balance));
    this.transactions.append("\n");

    String report = this.transactions.toString();
    this.resetTransactionLog();
    return report;
  }

  /**
   * Adds the monthly interest payment to the account balance.
   */
  private void accrueMonthlyInterest(){
    int interestAmount = (int) (this.balance * this.rate / (12 * 100));
    this.depositFunds(interestAmount, "Monthly interest @" + this.rate + "%");
  }
}
```

Repetition bad for:

- Readability
- Debugging
- Maintainability
- Extensibility

⋮

Inheritance

We can establish a new kind of subtype relationship, a <u>subclass</u> relationship, between two classes with the extends keyword.

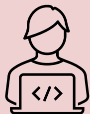
```
class B extends A {...}
```

A (superclass)

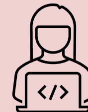
B (subclass)

Objects with (dynamic) type B "inherit" the state (fields) and behaviors (methods) from A (and can define their own fields + methods to "specialize" the type)

We can use inheritance to "extract up" common behaviors to a superclass and reduce code duplication.



Coding Demo: The Account Superclass



- "Extract up" common code
- Think about visibility modifiers

Protected Visibility

So far, we've discussed two visibility modifiers:

public = freely visible to every class, the "client interface"

private = visible only within that class, fully encapsulated

guards the class invariant

With inheritance, we'll sometimes want a third option

protected = visible within the class and its subclasses

gives extra tools to subclass developers: "specialization interface"

Good class design requires carefully considering visibility to manage both interactions

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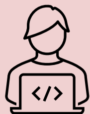
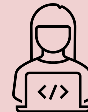
Why shouldn't we mark the fields in a superclass as `protected`?

- Subtype objects may not have these fields. **(A)**
- Subclasses might not know about these fields' invariants. **(B)**
- Subclasses may want to declare their own fields. **(C)**
- We should... access to the state could be useful in the subclass. **(D)**



Coding Demo: The Account Subclasses



- Identify "specialized" states / behaviors
- Inherit the rest

Method Overrides

When we override a method in the subclass, we <u>replace</u> its definition from the superclass

- same method signature (name, params)
- "shadowed" by dynamic dispatch
- should still conform to superclass specs, but can refine them
- annotate with @Override and write fresh refined specs

The super Keyword

Lets us "dispatch up" to higher method definition

calling super.<method name>() invokes the next higher up definition of <method name>

Useful to do extra work in override, then refer back to superclass definition

super( ), perhaps with arguments, calls superclass constructor to set up those inherited fields

- first line of subclass constructor must be superconstructor call

* By default, Java inserts no-argument super() call, IF there isn't a no-arguments constructor, this can't happen

An Encapsulation Problem

```
public class Account {
  /** Reassigns the transaction log to a new `StringBuilder` object that contains this
   *   month's initial account balance. This method must be  called at the start of every
   *   month (i.e., from the constructor and during the execution of `transactionReport()`). */
 private void resetTransactionLog() { … }

 public String transactionReport() { … this.resetTransactionLog(); … }
}
```

If the subclass overrides transactionReport() and doesn't call super.transactionReport(), this will break the Account class invariant.

Abstract Classes

classes and interfaces are two "extremes"

class = complete definition of all methods, instantiable

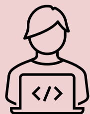
interface = no method definitions, just signatures, not instantiable

abstract classes are middle ground; offer some complete definitions and declare some abstract methods with defs left as responsibility for subclass

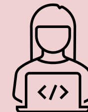
missing method defs = not instantiable

subclass must either

- provide definitions for all abstract methods
- be abstract itself



Coding Demo: One More Refactoring

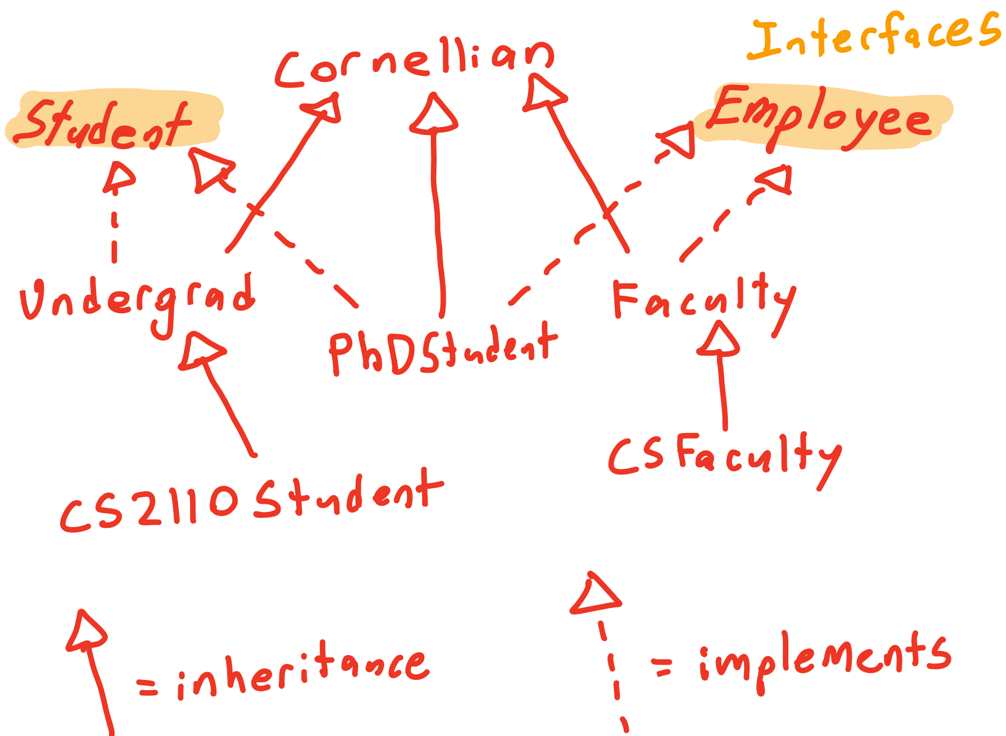


- mark transactionReport() as final to prevent subclasses from overriding and breaking Account invariant

- add abstract method call closeOutMonth() to let subclasses define specialized end-of-month things to go on transaction report

Type Hierarchies and Single Inheritance

Interfaces and inheritance let us build complex, deep type hierarchies



Java's single-inheritance rule:

Every* class has exactly one parent class (i.e., immediate superclass)

*choose wisely, this locks you into a rigid relationship

A class can implement any number of interfaces

- interfaces simply promise existence of behaviors
- often prefer interfaces to inheritance, unless there's significant code reuse