CSE201: Advanced Programming

Lecture 21: Introduction to Design Patterns

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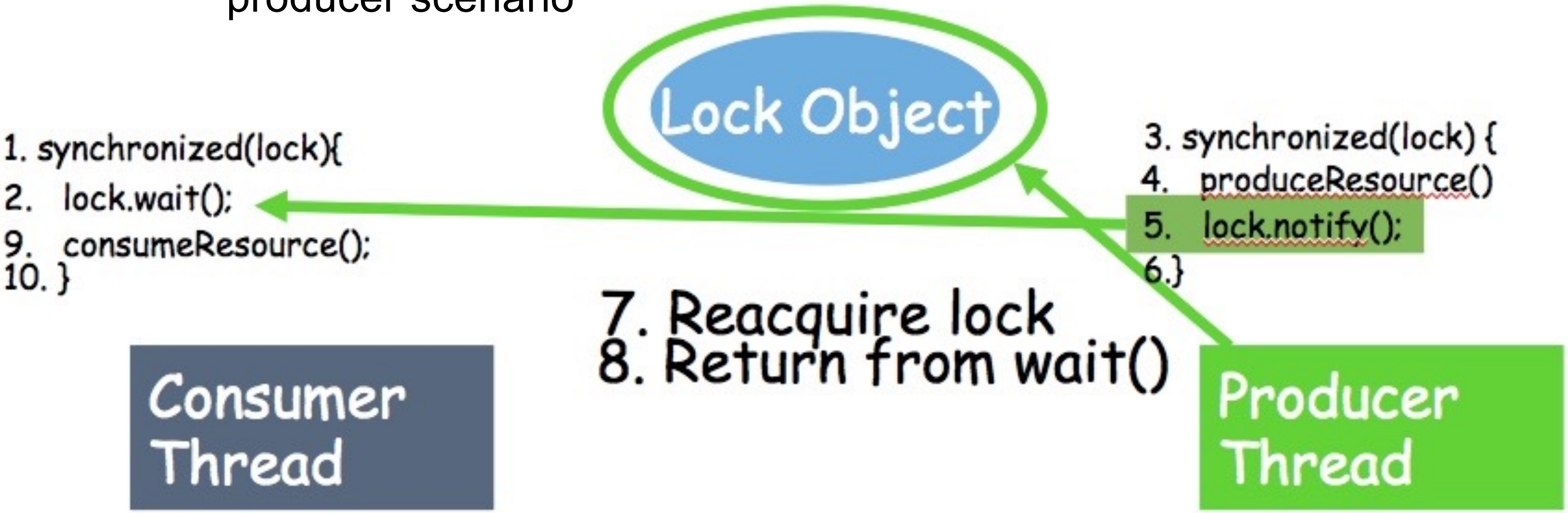
Last Lecture

- ***Critical section:*** a block of code that access shared modifiable data or resource that should be operated on by only one thread at a time.
- ***Mutual exclusion:*** a property that ensures that a critical section is only executed by a thread at a time
- Each object has a "**monitor**" that is a token used to determine which application **thread** has control of a particular **object** instance
- Producer consumer problem
    - We need to synchronize between transactions, for example, the consumer-producer scenario



Today's Lecture

- One remaining topic in multithreading
    - Deadlocks
- Introduction to design patterns
    - Iterator
    - Singleton
    - Flyweight
    - (Acknowledgement: CSE331, University of Washington)


DEADLOCK

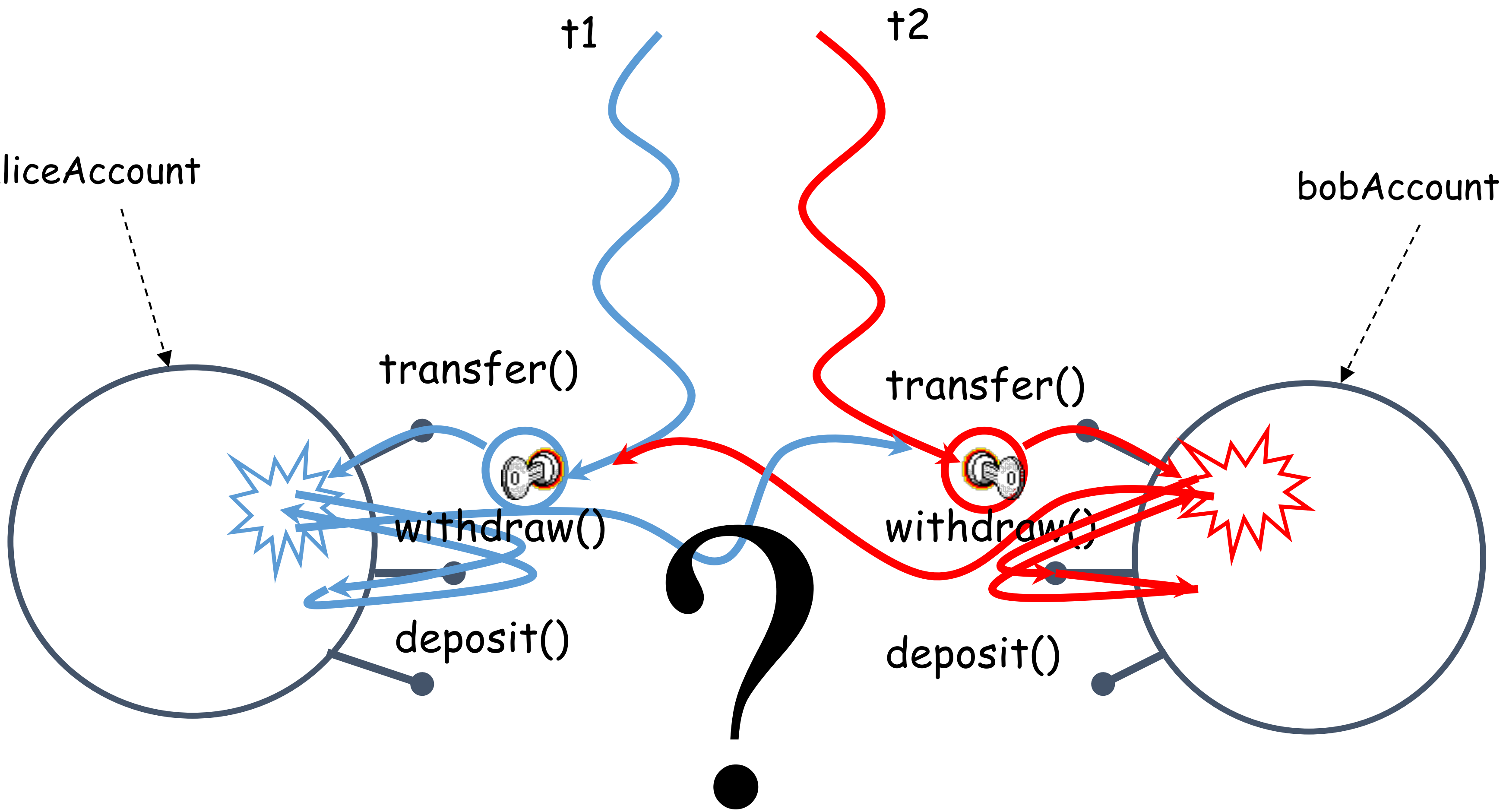
Let's Code a Deadlock

```
public class BankAccount {

    private volatile float balance;

    public synchronized void deposit(float amount) {
        balance += amount;
    }

    public synchronized void withdraw(float amount) {
        balance -= amount;
    }

    public synchronized void transfer(float amount,
                                      BankAccount target) {
        withdraw(amount);
        target.deposit(amount);
    }
}
```

```
public class MoneyTransfer implements Runnable {
    private BankAccount source, target;
    private float amount;
    public MoneyTransfer(BankAccount from,
                         BankAccount to, float amount) {
        this.source = from;
        this.target = to;
        this.amount = amount;
    }
    public void run() {
        source.transfer(amount, target);
    }
}
```

```
BankAccount aliceAccount = new BankAccount();
BankAccount bobAccount = new BankAccount();
...
// At one place
Runnable transaction1 = new MoneyTransfer(aliceAccount, bobAccount, 1200);
Thread t1 = new Thread(transaction1);
t1.start();

// At another place
Runnable transaction2 = new MoneyTransfer(bobAccount, aliceAccount, 700);
Thread t2 = new Thread(transaction2);
t2.start();
```

Let’s Analyze Our Bank Transaction



Deadlock Avoidance

- **Deadlock occurs when multiple threads need the same set of locks but obtain them in different order**
- Not so easy to avoid deadlocks
- It’s an active research area

Let’s try simple remedies to fix our Bank Transaction program

Deadlock Avoidance

- Lock ordering
  - Ensure that all locks are taken in same order by any thread
- Lock timeout
  - Put a timeout on lock attempts
    - Not possible with monitor locks
      - You will need java.util.concurrent.ReentrantLock

Now Let's Resolve the Deadlock

```
public class BankAccount {

    private volatile float balance;
    final int account_id;

    public BankAccount(int i) { account_id = i; }

    public synchronized void deposit(float amount) {
        balance += amount;
    }

    public synchronized void withdraw(float amount) {
        balance -= amount;
    }

    public synchronized void transfer(float amount,
                                      BankAccount target) {
        withdraw(amount);
        target.deposit(amount);
    }
}
```

```
public class MoneyTransfer implements Runnable {
    private BankAccount source, target;
    private float amount;
    public MoneyTransfer(BankAccount from,
                         BankAccount to, float amount) {
        this.source = from;
        this.target = to;
        this.amount = amount;
    }
    public void run() {
        Object obj1 = null, obj2 = null;
        if(source.account_id > target.account_id) {
            obj1=target; obj2=source;
        }
        else { obj1=source; obj2=target; }
        synchronized(obj1) { synchronized(obj2) {
                source.transfer(amount, target);
        } }
    }
}
```

```
BankAccount aliceAccount = new BankAccount(1); // account_id = 1;
BankAccount bobAccount = new BankAccount(2);   // account_id = 2;
...
// At one place
Runnable transaction1 = new MoneyTransfer(aliceAccount, bobAccount, 1200);
Thread t1 = new Thread(transaction1);
t1.start();

// At another place
Runnable transaction2 = new MoneyTransfer(bobAccount, aliceAccount, 700);
Thread t2 = new Thread(transaction2);
t2.start();
```

- We are using lock ordering technique here to resolve the deadlock
- Lock on BankAccount objects are taken in run() method as per the ascending order value of the account_id
    - Recall monitor locks are reentrant

Where are we as of now

- **CSE201 Post Conditions**
  1. Students are able to demonstrate the knowledge of basic principles of Object Oriented Programming such as encapsulation (classes and objects), interfaces, polymorphism and inheritance; by implementing programs ranging over few hundreds lines of code
  2. Implement basic event driven programming, exception handling, and threading
     - Already covered little bit of event driven programming in refresher module (Day 3) but we will see more
  3. Students are able to analyze the problem in terms of use cases and create object oriented design for it. Students are able to present the design in UML
     - Already covered little bit of UML but we will see more
  4. Students are able to select and use a few key design pattern to solve a given problem in hand
     - Lectures 21 — 24 (lectures 25/26 will be endsem review)
  5. Students are able to use common tools for testing (e.g., JUnit), debugging, and source code control as an integral part of program development
     - Will turn green by end of this week

Let’s change gears…

Design Patterns

What is Design Pattern

- It is a solution for a repeatable problem in the software design
- This is not a complete design for a software system that can be directly transformed into code
- It is a description or template for how to solve the problem that can be used in many different situations

Why Study Patterns

- Reuse tried, proven solutions
  - Provides a head start
  - Avoids gotchas later (unanticipated things)
  - No need to reinvent the wheel
- Establish common terminology
  - Design patterns provide a common point of reference
  - Easier to say, “We could use Strategy here.”
- Provide a higher level prospective
  - Frees us from dealing with the details too early

“GoF” (Gang of Four) patterns

- **Creational Patterns** *(abstracting the object-instantiation process)*
  - Factory Method — Abstract Factory — Singleton
  - Builder — Prototype
- **Structural Patterns** *(how objects/classes can be combined)*
  - Adapter — Bridge — Composite
  - Decorator — Facade — Flyweight
  - Proxy
- **Behavioral Patterns** *(communication between objects)*
  - Command — Interpreter — Iterator
  - Mediator — Observer — State
  - Strategy — Chain of Responsibility — Visitor
  - Template Method

In 1990 a group called the Gang of Four or "GoF” (Gamma, Helm, Johnson, Vlissides) compile a catalog of design patterns in the book “Design Patterns: Elements of Reusable Object-Oriented Software”

Pattern: Iterator

objects that traverse collections

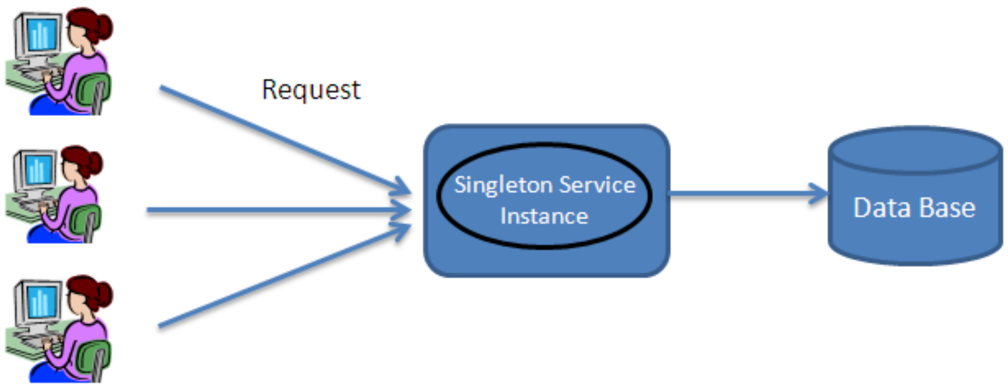
Pattern: Iterator

- Recurring Problem
  - How can you loop over all objects in any collection. You don't want to change client code when the collection changes. Want the same methods
- Solution
  1. Provide a standard *iterator* object supplied by all data structures
  2. The implementation performs traversals, does bookkeeping
  3. The implementation has knowledge about the representation
  4. Results are communicated to clients via a standard interface
- Consequences
  - Can change collection class details without changing code to traverse the collection

Pattern: Singleton

A class that has only a single instance

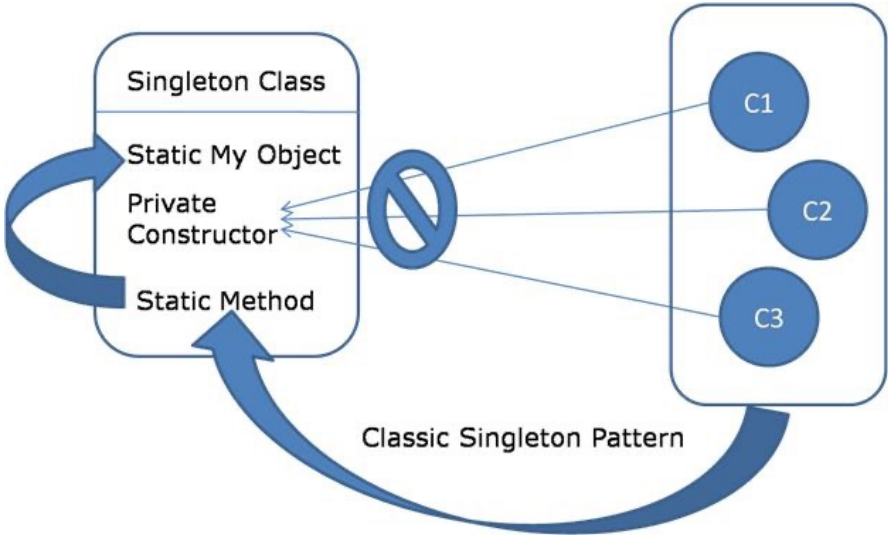
Pattern: Singleton



- Recurring problem
  - Sometimes we only ever need one instance of a particular class
  - It should be illegal to have another instance of the same class
- Solution
  - Singleton pattern – ensuring that a class has at most one instance
  - Providing global access to that instance

Fig. source: https://rajneekanth.wordpress.com/2014/04/11/what-are-design-patterns/

Implementing Singleton



1. Make constructor private so that no client is able to call it from outside
2. Declare a single private static instance of the class
3. Write a getInstance() method (or similar) that allows access to the single instance
   - Ensure thread safety in case multiple threads can access this method

Singleton Example

```
public class RandomGenerator {
    private static RandomGenerator gen = null;

    public static RandomGenerator getInstance()
    {
        if (gen == null) {
            gen = new RandomGenerator();
        }

        return gen;
    }

    private RandomGenerator() {}

    ...
}
```

- Creates a new random generator
- Clients will not use the constructor directly but will instead call getInstance to obtain
  a RandomGenerator obect that is shared by all classes in the application
- Lazy initialization
  - Can wait until client asks for the instance to create it
  - How to ensure thread safety?

Singleton Comparator

```
public class LengthComparator
                implements Comparator<String> {

    private static LengthComparator comp = null;

    public static LengthComparator getInstance()
    {
        if (comp == null) {
            comp = new LengthComparator();
        }
        return comp;
    }

    private LengthComparator() {}

    public int compare(String s1, String s2) {
        return s1.length() - s2.length();
    }
}
```

- Comparators make great singletons because they have no state
- Saves memory by not allowing the creation of more than one object

Pattern: Flyweight

a class that has only one instance for each unique state

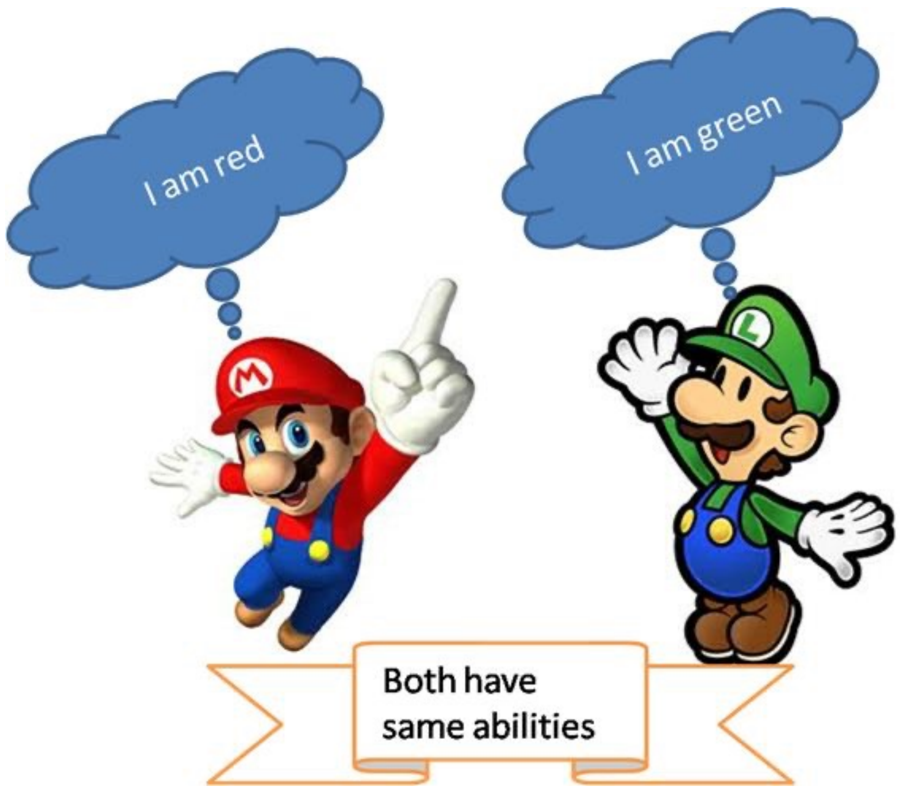
Pattern: Flyweight

- Problem
  - **Redundant objects** can bog down the system
    - Many objects have the same state

  - Example: `File` objects that represent the same file on disk
    - `new File("chatlog.txt")`
    - `new File("chatlog.txt")`
    - `new File("chatlog.txt")`
      `...`
    - `new File("notes.txt")`

  - Example: Date objects that represent the same date of the year
    - `new Date(4, 18)`
    - `new Date(4, 18)`

Pattern: Flyweight



- An assurance that no more than one instance of a class will have identical state
  - Achieved by caching identical instances of objects.
  - Similar to singleton, but one instance for each unique object state
  - Useful when there are many instances, but many are equivalent

Fig source: http://www.c-sharpcorner.com/UploadFile/SukeshMarla/learn-design-pattern-flyweight-pattern/

Implementing a Flyweight (1/2)

```
public class Flyweighted {
    private static Map<KeyType, Flyweighted> instances
             = new HashMap<KeyType, Flyweighted>();

    private Flyweighted(...) { ... }

    public static Flyweighted getInstance(KeyType key) {
        if (!instances.contains(key)) {
            instances.put(key, new Flyweighted(key));
        }
        return instances.get(key);
    }
}
```

Implementing a Flyweight (2/2)

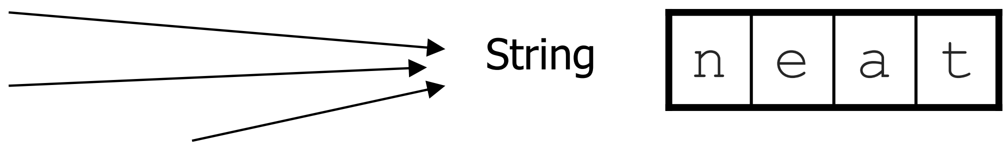
```
public class Point {
    private int x, y;

    public Point(int x, int y) {
        this.x = x;
        this.y = y;
    }

    public int getX() { return x; }
    public int getY() { return y; }

    public String toString() {
        return "(" + x + ", " + y + ")";
    }
}
```

```
public class Point {

    private static Map<String, Point> instances =
        new HashMap<String, Point>();

    public static Point getInstance(int x, int y)
    {
        String key = x + ", " + y;
        if (!instances.containsKey(key)) {
            instances.put(key, new Point(x, y));
        }
        return instances.get(key);
    }

    private final int x, y;  // immutable

    private Point(int x, int y) {
        this.x = x;
        this.y = y;
    }
    public int getX() { return x; }
    public int getY() { return y; }
    public String toString() {
        return "(" + x + ", " + y + ")";
    }
}
```

Flyweighting in String by JVM

- The possible combinations for Strings is close to infinite, hence JVM maintains a cache for strings, called the **string constant pool**
  - It is empty at startup and is filled constantly during the lifecycle of the JVM
- Java String objects are automatically flyweighted by the JVM **whenever** possible
  - If you declare two string variables that point to the same literal.
  - If you concatenate two string literals to match another literal

```
String a = "neat";
String b = "neat";
String c = "n" +
"eat";
```



Next Lecture

- More design patterns
- Quiz-5
  - Syllabus: Lectures 17-20