18-0: **Arrays**

- Array Advantages
  - Elements are stored in sequential memory locations
  - Fast lookup of element by index
- Array Disadvantages
  - Difficult to resize the array
  - Adding elements to the middle is expensive

18-1: **Linked Lists**

- Linked List Advantages
  - Easy to resize a linked list
  - Adding elements to the middle easy
- Likned List Disadvantages
  - Elements are *not* stored in sequential memory locations
  - Finding the nth element in the list is slower

18-2: **Linked List Node**

```
public class LinkedListNode
{
   int data;
   LinkedListNode next;
}
```

- This looks very strange – recursive data structure! If a LinkedListNode contans a LinkedListNode, which contains a LinkedListNode, where does it stop?

18-3: **Linked List Node**

```
public class LinkedListNode
{
   int data;
   LinkedListNode next;
}
```

- This looks very strange – recursive data structure! If a LinkedListNode contans a LinkedListNode, which contains a LinkedListNode, where does it stop?
- Remember that class variables are only created when "new" is called – otherwise, you just have a pointer.

18-4: **Linked List Node**

```
public class LinkedListNode
{
   int data;
   LinkedListNode next;
}
```

What does memory look like when we do this:

```
LinkedListNode n = new LinkedListNode
```

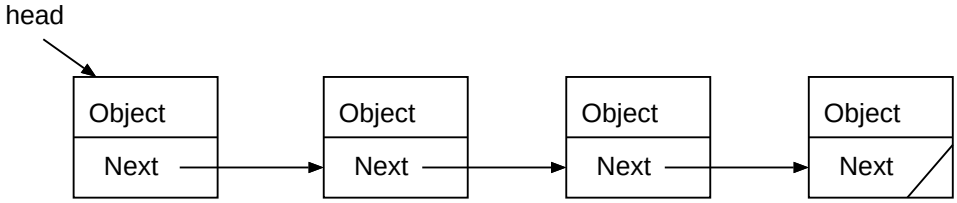
18-5: **Linked List Node**

```
public class LinkedListNode
{
   int data;
   LinkedListNode next;
}
```

What does memory look like when we do this:

```
LinkedListNode n = new LinkedListNode();
n.data = 3;
n.next = new LinkedListNode();
```

18-6: **Linked Lists**



18-7: **Linked Lists**

- Each element in the list is a *node*
- Each node contains:
  - An Object that represents the data stored in the node
  - A *next* pointer

18-8: **Linked Lists**

```
public class ListNode
{
   public Object data;
   public ListNode next;

   public ListNode(Object d)
   {
      data  = d;
      next = null;
   }

   public ListNode(Object d, ListNode n)
   {
      data = d;
      next = n;
   }
}
```

18-9: **Linked Lists**

- What would memory look like after the following:

```
ListNode list = null;
for (int i = 0; i < 5; i++)
{
    list = new ListNode(new Integer(i), list);
}
```

18-10: **Linked Lists**

- Our linked list class needs to keep track of the *head* of the list
- All other elements are reachable from the head
    - Follow the next ponters

18-11: **Linked Lists**

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   // Methods to manipulate the list
}
```

18-12: **Linked Lists**

- Linked List Methods
    - `insert(Object o)` Insert an element at the front of the list
    - `insertAt(Object o, int index)` Insert an element at a specific index
    - `get(int index)` Get an element at a specified index
    - `remove(int index)` Remove an element at a specified index

18-13: **Linked Lists**

- `void insert(Object o)`

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public void insert(Object o) { ... }
}
```

18-14: **Linked Lists**

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public void insert(Object o)
   {
      ListNode newElem = new ListNode(o);
      newElem.next = head;
      head = newElem;
   }
}
```

18-15: **Linked Lists**

- What if we changed the order a little bit?

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public void insert(Object o)
   {
      ListNode newElem = new ListNode(o);
      head = newElem;
      newElem.next = head;
   }
}
```

18-16: **Linked Lists**

- What if we changed the order a little bit?

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public void insert(Object o)
   {
      ListNode newElem = new ListNode(o); // DOES NOT WORK!!
      head = newElem;
      newElem.next = head;
   }
}
```

18-17: **Linked Lists**

- We can use constructors to make our life easier ...

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public void insert(Object o)
   {
      head = new ListNode(o, head);
   }
}
```

18-18: **Linked Lists**

- `Object get(int index)`

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public Object get(int index) { ... }
}
```

18-19: **Linked Lists**

- `Object get(int index)`

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public Object get(int index)
```

```
   {
      ListNode tmp = head;
      for (int i = 0; i < index; i++)
         tmp = tmp.next;
      return tmp.data;
   }
}
```

18-20: **Linked Lists**

- `Object get(int index)`

```
public class LinkedList
{
   private ListNode head;
   public LinkedList()
   {
      head = null;
   }
   public Object get(int index)
   {
      ListNode tmp = head;
      for (int i = 0; i < index; i++)
      {
         if (tmp == null)     // Added some error checking ...
            return null;
         tmp = tmp.next;
      }
      return tmp.data;
   }
}
```

18-21: **Linked Lists**

- `Object get(int index)`
  - Can we do this recursively?

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }

   public Object get(int index, ListNode list) { ... }

   public Object get(int index)
   {
      return get(index, head);
   }
}
```

18-22: **Linked Lists**

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }
   public Object get(int index, ListNode list)
   {
      if (index == 0)
      {
         return list.data;
      }
      return get(index - 1, list.next);
   }
   public Object get(int index)
   {
      return get(index, head);
   }
}
```

18-23: **Linked Lists**

- `Object last()`
  - Return the last element of the list (leaving list unchanged)

18-24: **Linked Lists**

```
public class LinkedList
{
   private ListNode head;

   public LinkedList()
   {
      head = null;
   }
   public Object last()
   {
      ListNode tmp = head;
      while (tmp.next != null)
      {
          tmp = tmp.next;
      }
      return tmp.data;
   }
}
```

18-25: **Practical Experience**

- Download LinkedListNode, LinkedList, LinkedListDriver from website
- Implement the methods (ordered from easiest to hardest)
    - deleteFirst
    - insertAtEnd
    - deleteLast