What Will We Do Today?

Meet Martin (well, 2 of us)
Meet Martin

Martin D. Hellwig != Martin F. Hellwig

Both are amazing (and German),
but I’m the one on the left
What Is Data?
What Is Data?

First of all ....
What Is Data?

First of all ....

Data isn't.
What Is Data?

First of all ....

Data isn't.

Unless you are referring to Lt. Cmdr. Data., of course
What Is Data?

First of all ....

Data isn't.

Unless you are referring to Lt. Cmdr. Data., of course
What Is Data?

Otherwise....
What Is Data?

Otherwise....

Data are.
What Is Data?

Otherwise....

Data are.

Data is the plural of datum.
What Is Data?
What Is Are Data?
What Are Data?
What Are Data?

Little pieces of "stuff"
What Are Data?

Little pieces of "stuff"

Numbers for example
What Are Data?

Little pieces of "stuff"

Numbers for example 2 3 7 8
What Are Data?

Little pieces of "stuff"

Numbers for example
What Are Data?

Little pieces of "stuff"

Numbers for example

Or Strings
What Are Data?

Little pieces of "stuff"

Numbers for example

Or Strings
What Are Data?

Little pieces of "stuff"

Numbers for example

Or Strings
What Are Data?

Little pieces of "stuff"

Numbers for example

Or Strings
What Are Data?

There are many forms of data
What Are Data?

There are many forms of data:

- Images
- Sound Files
- Videos
- etc.
How are data stored?
How are data stored?

Numbers
How are data stored?

Numbers

Everything Else
How are data stored?

Numbers

Not terribly hard

Everything Else
How are data stored?

Numbers
Not terribly hard

Everything Else
A bit more complex
How are data stored?

Numbers
Not terribly hard

Everything Else
A bit more complex

So let's start here!
A quick trip to the 80s
A quick trip to the 80s
A quick trip to the 80s
A quick trip to the 80s
A quick trip to the 80s
OK, maybe the 60s
OK, maybe the 60s
OK, maybe the 60s

Capacity: 80 bytes
What are bytes?
What are bytes?

One byte consists of 8 bits.
What are bytes?

One byte consists of 8 bits.

And what is a bit, then?
What are bytes?

One byte consists of 8 bits.

And what is a bit, then?

The smallest unit in a computer.
What does a Bit look like?
What does a Bit look like?

Like This

Like This 2
What does a Bit look like?

Like This

Or This
What does a Bit look like?

Like This

Or This
What does a Bit look like?

Like This
Not punched

Or This
Punched
What does a Bit look like?

Like This
Not punched

Or This
Punched
What about all the other numbers?
What about all the other numbers?

Computers only know 0 and 1.
What about all the other numbers?

Computers only know 0 and 1. We can use these two to represent all other numbers.
What about all the other numbers?

Computers only know 0 and 1.
We can use these two to represent all other numbers.

... and just about everything else.
How?

Binary Numbers
How?

Binary Numbers

Every decimal number can be converted into a binary and vice versa.
How?

Let's look at a decimal
How?

Let's look at a decimal

21
How?

Let's look at a decimal

21

Ones
How?

Let's look at a decimal

21

Tens  Ones
How?

Let's look at a decimal

21

(1*1)

Tens

Ones
How?

Let's look at a decimal

21

(1*1)+(2*10)

Tens

Ones
How?

Let's look at a decimal

\[(1 \times 1) + (2 \times 10) = 21\]
How?

Let's look at a decimal

21

Tens  Ones
How?

Let's look at a decimal

5921

Tens  Ones
How?

Let's look at a decimal

5921

Thousands

Hundreds

Tens

Ones
How?

Let's look at a decimal

Each digit can assume 10 different "states" (0,1,2,...,9)

Each digit is worth ten times as much as its right neighbor
How?

In a binary number
In a binary number each digit can assume 2 different states (0 and 1)
How?

In a binary number each digit can assume 2 different states (0 and 1)

each digit is worth twice as much as its right neighbor
How?

In a binary number

10

Twos  Ones
How?

In a binary number

\[ 10 = (0 \times 1) \]

Twos  Ones
How?

In a binary number

10 \[(0 \times 1) + (1 \times 2)\]
How?

In a binary number

10

(0*1)+(1*2)=2

Twos

Ones
Can you guess?
Can you guess?

What would this binary number look like in decimal?

101011
Can you guess?

What would this binary number look like in decimal?

101011

\[(1*1)+(1*2)+(0*4)+(1*8)+(0*16)+(1*32)\]
Can you guess?
What would this binary number look like in decimal?

101011
1+2+0+8+0+32 =
Can you guess?

What would this binary number look like in decimal?

101011

1+2+0+8+0+32 = 43
Now let's try the opposite
Now let's try the opposite

Convert this decimal number into its binary equivalent
Now let's try the opposite

Convert this decimal number into its binary equivalent

99
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

$2^0 = 1$
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

$2^1 = 2$
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

$2^2 = 4$
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

\[ 2^3 = 8 \]
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

$2^4 = 16$
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

\[ 2^5 = 32 \]
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

\[2^6 = 64\]
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

\[ 2^7 = 128 \]
Now let's try the opposite

Convert this decimal number into its binary equivalent

99

What's the largest power of two that fits into 99?

$2^7=128$ oops....
Now let's try the opposite

Convert this decimal number into its binary equivalent

99
Now let's try the opposite

Convert this decimal number into its binary equivalent

99
Now let's try the opposite

Convert this decimal number into its binary equivalent

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Now let's try the opposite

Convert this decimal number into its binary equivalent

99

<table>
<thead>
<tr>
<th>128</th>
<th>64</th>
<th>32</th>
<th>16</th>
<th>8</th>
<th>4</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td></td>
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</tbody>
</table>
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99

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</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64=35

<table>
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<th>128</th>
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</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99 - 64 = 35

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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64-32=3

<table>
<thead>
<tr>
<th>128</th>
<th>64</th>
<th>32</th>
<th>16</th>
<th>8</th>
<th>4</th>
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</tr>
</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64-32=3

<table>
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</thead>
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<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64-32-0=3
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64-32-0-0=3

<table>
<thead>
<tr>
<th>128</th>
<th>64</th>
<th>32</th>
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<th>8</th>
<th>4</th>
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<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64-32-0-0-0-0=3

<table>
<thead>
<tr>
<th align="right">128</th>
<th align="right">64</th>
<th align="right">32</th>
<th align="right">16</th>
<th align="right">8</th>
<th align="right">4</th>
<th align="right">2</th>
<th align="right">1</th>
</tr>
</thead>
<tbody>
<tr>
<td align="right">0</td>
<td align="right">1</td>
<td align="right">1</td>
<td align="right">0</td>
<td align="right">0</td>
<td align="right">0</td>
<td align="right">0</td>
<td align="right">0</td>
</tr>
</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

\[
99-64-32-0-0-0-0-2=1
\]

<table>
<thead>
<tr>
<th>128</th>
<th>64</th>
<th>32</th>
<th>16</th>
<th>8</th>
<th>4</th>
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<tbody>
<tr>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Now let's try the opposite

Convert this decimal number into its binary equivalent

99-64-32-0-0-0-0-2-1=0

<table>
<thead>
<tr>
<th>128</th>
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<th>32</th>
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<th>8</th>
<th>4</th>
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<td>1</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Now let's try the opposite

The decimal number 99 is equivalent to the binary number 1100011.
But this isn't 1964

Capacity: 80 bytes
A typical DVD: 4.7 Gigabytes

Cards needed for your movie: 
4,700,000,000 / 80
But this isn't 1964

Capacity: 80 bytes
A typical DVD: 4.7 Gigabytes

Cards needed for your movie: 
470,000,000 / 8 = 58,750,000
That's a lot of cards!

The 150 card stack on my desk is 1 inch high
That's a lot of cards!

So a stack of 58,750,000 cards should be approximately

58,750,000 / 150 inches
That's a lot of cards!

So a stack of 58,750,000 cards should be approximately 32,640 feet high.
That's a lot of cards!

So a stack of 58,750,000 cards should be approximately 6.18 miles high.
Back to the Future...
Back to the Future...

How does a tape work?
Back to the Future...
How does a tape work?
Back to the Future...

How does a tape work?

Courtesy of DATATAPE Incorporated, Copyright © All rights reserved
Back to the Future...

How about a hard disk?
Back to the Future...

How about a hard disk?
Back to the Future...
How about a hard disk?

It's still all zeroes and ones!
How do we get the data?
How do we get the data?
We'll have to tell the drive where it is.
How do we get the data?

We'll have to tell the drive where it is.
How do we get the data?
We'll have to tell the drive where it is.

Like giving somebody your address.
Addresses in Memory
Addresses in Memory

```
00020480 c0 66 fb 81 ff ff ff ff 40 67 fb 81 ff ff ff ff | .f......@g......|
00020490 c0 67 fb 81 ff ff ff ff ff 40 68 fb 81 ff ff ff ff | .g......@h......|
000204a0 c0 68 fb 81 ff ff ff ff ff 40 69 fb 81 ff ff ff ff | .h......@i......|
000204b0 c0 69 fb 81 ff ff ff ff ff 40 6a fb 81 ff ff ff ff | .i......@j......|
000204c0 c0 6a fb 81 ff ff ff ff ff 40 6b fb 81 ff ff ff ff | .j......@k......|
000204d0 c0 6b fb 81 ff ff ff ff ff 40 6c fb 81 ff ff ff ff | .k......@l......|
000204e0 c0 6c fb 81 ff ff ff ff ff 40 6d fb 81 ff ff ff ff | .l......@m......|
000204f0 c0 6d fb 81 ff ff ff ff ff 40 6e fb 81 ff ff ff ff | .m......@n......|
00020500 c0 6e fb 81 ff ff ff ff ff 40 6f fb 81 ff ff ff ff | .n......@o......|
00020510 c0 6f fb 81 ff ff ff ff ff 40 70 fb 81 ff ff ff ff | .o......@p......|
00020520 c0 70 fb 81 ff ff ff ff ff 40 71 fb 81 ff ff ff ff | .p......@q......|
00020530 c0 71 fb 81 ff ff ff ff ff 40 72 fb 81 ff ff ff ff | .q......@r......|
00020540 c0 72 fb 81 ff ff ff ff ff 40 73 fb 81 ff ff ff ff | .r......@s......|
00020550 c0 73 fb 81 ff ff ff ff ff 40 74 fb 81 ff ff ff ff | .s......@t......|
00020560 c0 74 fb 81 ff ff ff ff ff 40 75 fb 81 ff ff ff ff | .t......@u......|
00020570 c0 75 fb 81 ff ff ff ff ff 40 76 fb 81 ff ff ff ff | .u......@v......|
00020580 c0 76 fb 81 ff ff ff ff ff 40 77 fb 81 ff ff ff ff | .v......@w......|
00020590 c0 77 fb 81 ff ff ff ff ff 40 78 fb 81 ff ff ff ff | .w......@x......|
000205a0 c0 78 fb 81 ff ff ff ff ff 40 79 fb 81 ff ff ff ff | .x......@y......|
000205b0 c0 79 fb 81 ff ff ff ff ff 40 7a fb 81 ff ff ff ff | .y......@z......|
000205c0 c0 7a fb 81 ff ff ff ff ff 40 7b fb 81 ff ff ff ff | .z......@{......|
000205d0 c0 7b fb 81 ff ff ff ff ff 40 7c fb 81 ff ff ff ff | {...}......|
000205e0 c0 7c fb 81 ff ff ff ff ff 40 7d fb 81 ff ff ff ff | {...}......|
000205f0 c0 7d fb 81 ff ff ff ff ff 40 7e fb 81 ff ff ff ff | {...}......|
```
# Addresses in Memory

<table>
<thead>
<tr>
<th>Address</th>
<th>Data</th>
<th>Data</th>
<th>Data</th>
<th>Data</th>
<th>Data</th>
<th>Data</th>
<th>Data</th>
<th>Data</th>
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</thead>
<tbody>
<tr>
<td>00020480</td>
<td>c0 66 fb</td>
<td>81 ff ff ff</td>
<td>ff ff ff</td>
<td>40 67 fb</td>
<td>81 ff ff ff</td>
<td>ff ff ff</td>
<td>.f........</td>
<td>.g........</td>
<td>.h........</td>
<td>.i........</td>
<td>.j........</td>
<td>.k........</td>
<td>.l........</td>
<td>.m........</td>
<td>.n........</td>
<td>.o........</td>
<td>.p........</td>
<td>.q........</td>
<td>.r........</td>
<td>.s........</td>
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<td>.x........</td>
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<td>ff ff ff</td>
<td>40 68 fb</td>
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<td>ff ff ff</td>
<td>.g........</td>
<td>.h........</td>
<td>.i........</td>
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<td>.w........</td>
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<td>.y........</td>
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<td>ff ff ff</td>
<td>40 69 fb</td>
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<td>ff ff ff</td>
<td>.h........</td>
<td>.i........</td>
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<td>.z........</td>
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<tr>
<td>000204b0</td>
<td>c0 69 fb</td>
<td>81 ff ff ff</td>
<td>ff ff ff</td>
<td>40 6a fb</td>
<td>81 ff ff ff</td>
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<td>.j........</td>
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<tr>
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<td>ff ff ff</td>
<td>40 6b fb</td>
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<td>ff ff ff</td>
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<td>.k........</td>
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Addresses in Memory

When we know the address
We can readily access data
Addresses in Memory

When we know the address
We can readily access data

We can also write to an address
Addresses in Memory

When we know the address
We can readily access data

We can also write to an address
Well, not just any address...
Addresses in Memory

When we know the address
We can readily access data

We can also write to an address
Well, not just any address...
... at least not safely
Why Should You Care?

As you begin programming, you will want to store some data.
Why Should You Care?

As you begin programming, you will want to store some data.

And you'll want to get it back later
How do you do that?
How do you do that?

Thankfully JavaScript does the hardest part for you.
How do you do that?

Thankfully JavaScript does the hardest part for you.

You just tell it that you want to create a "variable" (like a box for stuff) and it will find space in memory for you.
How do you do that?

Thankfully JavaScript does the hardest part for you

You just tell it that you want to create a "variable" (like a box for stuff) and it will find space in memory for you.

It will even keep track of the address and retrieve your stuff for you.
Whew!  
That was a lot of stuff!  

But we're done for the day!
One More Question

Today's Lecture Was

a) Amazing
b) Nice
c) Like Any Other
d) Not So Great
e) Horrible!