Recap: Reduction

<table>
<thead>
<tr>
<th>Level</th>
<th>Examples</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>software libraries</td>
<td>graphics, animation, robotics</td>
<td>networking, security, mathematics</td>
</tr>
<tr>
<td>high-level language</td>
<td>Python</td>
<td>C, Java, C++, Logo, LISP, Fortran, ML</td>
</tr>
<tr>
<td>machine language</td>
<td>ML(^3)</td>
<td>x86, CARDIAC, Z80</td>
</tr>
<tr>
<td>logic gates</td>
<td>equal, ifthenelse, add</td>
<td>memlookup, memwrite</td>
</tr>
<tr>
<td>basic logic gates</td>
<td>and, or, not</td>
<td>nor, nand, xor</td>
</tr>
<tr>
<td>physical bits</td>
<td>0,1 via high/low voltage</td>
<td>water pressure, kinetic energy</td>
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Does It End There?

- Of course, not.
- We can continue to build sophisticated programs out of simpler programs.
- The idea of **subroutines** (procedures, functions) makes this work.
Subroutines

- A lot of research in computer science is about designing and creating just the right set of subroutines, sometimes called libraries.
- You don’t have enough background yet to weigh in on these problems.
- But, there is an analogous set of problems where you are already an expert...

Sing-A-Long Programs

Gilligan's Island Theme
Just sit right back and you'll hear a tale, a tale of a fateful trip.
That started from this tropic port, aboard this tiny ship.
The mate was a mighty sailin' man, the skipper brave and sure.
Five passengers set sail that day, for a three hour tour, a three hour tour...
The weather started getting rough, the tiny ship was tossed.
If not for the courage of the fearless crew,
the Minnow would be lost; the Minnow would be lost.
The ship took ground on the shore of this uncharted desert isle,
with Gilligan, the Skipper too, the Millionaire, and his Wife,
the Movie Star, the Professor and Mary Ann, here on Gilligan's Isle.
In a cavern, in a canyon,
Excavating for a mine,
Dwelt a miner forty niner,
And his daughter Clementine.

Oh my darling, oh my darling,
Oh my darling, Clementine!
Thou art lost and gone forever
Dreadful sorry, Clementine.

Light she was and like a fairy,
And her shoes were number nine,
Herring boxes, without topses,
Sandals were for Clementine.

Oh my darling, oh my darling,
Oh my darling, Clementine!
Thou art lost and gone forever
Dreadful sorry, Clementine.

Drove she ducklings to the water
Ev'ry morning just at nine,
Hit her foot against a splinter,
Fell into the foaming brine.

Oh my darling, oh my darling,
Oh my darling, Clementine!
Thou art lost and gone forever
Dreadful sorry, Clementine.

Ruby lips above the water,
Blowing bubbles, soft and fine,
But, alas, I was no swimmer,
So I lost my Clementine.

Oh my darling, oh my darling,
Oh my darling, Clementine!
Thou art lost and gone forever
Dreadful sorry, Clementine.

How I missed her! How I missed her,
How I missed my Clementine,
But I kissed her little sister,
I forgot my Clementine.

Oh my darling, oh my darling,
Oh my darling, Clementine!
Thou art lost and gone forever
Dreadful sorry, Clementine.

Chorus Structure

Clementine

In a cavern, in a canyon,
Excavating for a mine,
Dwelt a miner forty niner,
And his daughter Clementine.

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Oh my darling, oh my darling,
Oh my darling, Clementine!
Thou art lost and gone forever
Dreadful sorry, Clementine.
Now, “Chorus” is its own little program, or a new statement in the language, that we can call whenever we need it.

Calling the subroutine does all the steps, then the program resumes from where the call took place.

Simplifies the program, easier to maintain, extend, fix.
**Shared Structure**

**All My Loving**
Lennon/McCartney

Close your eyes and I’ll kiss you,
Tomorrow I’ll miss you,
Remember I’ll always be true,
And then while I’m away,
I’ll write home every day,
And I’ll send all my loving to you.

I’ll pretend I am kissing,
The lips I am missing,
And hope that my dreams will come true,
And then while I’m away,
I’ll write home every day,
And I’ll send all my loving to you.
All my loving, I will send to you,
All my loving, darling, I’ll be true.

Close your eyes and I’ll kiss you,
Tomorrow I’ll miss you,
Remember I’ll always be true,
And then while I’m away,
I’ll write home every day,
And I’ll send all my loving to you.

All my loving, I will send to you,
All my loving, darling, I’ll be true,
All my loving.

Woo, all my loving, I will send to you.

**Deeper Nesting?**

subroutines can call subroutines

Close your eyes and I’ll kiss you,
Tomorrow I’ll miss you,
Remember I’ll always be true,
And then while I’m away,
I’ll write home every day,
And I’ll send all my loving to you.

I’ll pretend I am kissing,
The lips I am missing,
And hope that my dreams will come true,
And then while I’m away,
I’ll write home every day,
And I’ll send all my loving to you.
All my loving, I will send to you,
All my loving, darling, I’ll be true.

Close your eyes and I’ll kiss you,
Tomorrow I’ll miss you,
Remember I’ll always be true,
And then while I’m away,
I’ll write home every day,
And I’ll send all my loving to you.

All my loving, I will send to you,
All my loving, darling, I’ll be true,
All my loving.

Woo, all my loving, I will send to you.
More Structure

**Eight Days a Week** (Beatles)

<table>
<thead>
<tr>
<th>B</th>
<th>Ooh I need your love babe, guess you know it's true, Hope you need my love babe just like I need you,</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Hold me, love me, Hold me, love, Ain't got nothin' but love babe, Eight days a week.</td>
</tr>
<tr>
<td>Y</td>
<td>Love you ev'ry day girl, always on my mind, One thing I can say girl, love you all the time,</td>
</tr>
<tr>
<td>R</td>
<td>Hold me, love me, Hold me, love me, Ain't got nothin' but love babe, Eight days a week.</td>
</tr>
<tr>
<td>G</td>
<td>Eight days a week I love you, Eight days a week is not enough to show I care.</td>
</tr>
<tr>
<td>B</td>
<td>Ooh I need your love babe, guess you know it's true, Hope you need my love babe just like I need you,</td>
</tr>
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</table>

Building Structure

**Old Macdonald had a farm, E-I-E-I-O**

And on his farm he had a cow, E-I-E-I-O

*With a "moo" here and a "moo" there*

*Here a "moo" there a "moo"*

*Everywhere a "moo-moo"*

Old Macdonald had a farm, E-I-E-I-O

Old Macdonald had a farm, E-I-E-I-O

And on his farm he had a pig, E-I-E-I-O

*With a (snort) here and a (snort) there*

*Here a (snort) there a (snort)*

*Everywhere a (snort-snot)*

Old Macdonald had a farm, E-I-E-I-O

Old Macdonald had a farm, E-I-E-I-O

And on his farm he had a horse, E-I-E-I-O

*With a "neigh, neigh" here and a "neigh, neigh" there*

*Here a "neigh" there a "neigh"*

*Everywhere a "neigh-neigh"*

Old Macdonald had a farm, E-I-E-I-O

Old Macdonald had a farm, E-I-E-I-O

And on his farm he had a chick, E-I-E-I-O

*With a "cluck, cluck" here and a "cluck, cluck" there*

*Here a "cluck" there a "cluck"*

*Everywhere a "cluck-cluck"*

Old Macdonald had a farm, E-I-E-I-O

Old Macdonald had a farm, E-I-E-I-O

And on his farm he had a chick, E-I-E-I-O

*With a "cluck, cluck" here and a "cluck, cluck" there*

*Here a "cluck" there a "cluck"*

*Everywhere a "cluck-cluck"*

Old Macdonald had a farm, E-I-E-I-O

Old Macdonald had a farm, E-I-E-I-O

And on his farm he had a chick, E-I-E-I-O

*With a "cluck, cluck" here and a "cluck, cluck" there*

*Here a "cluck" there a "cluck"*

*Everywhere a "cluck-cluck"*

Old Macdonald had a farm, E-I-E-I-O
But Notice...

- Each time we “snort”, we follow it with “moo”.
- Each time we “neigh”, we follow it with “snort”.
- Each time we “cluck”, we follow it with “neigh”.
- Let’s put the earlier noises into the later subroutines...

Top Level Song

- At the highest level, the song consists of one verse per animal.
Cow

- Needs to know two things
  - Sing the verse
  - Sing the animal sounds (and highlight)

Pig

- Animal-sound subroutine oinks
  - then calls the cow’s sound to finish the verse!
Horse

- Animal-sound subroutine neighs
  - then calls the pig’s sound
    - which calls the cow’s sound to finish the verse!

Chick

- Animal-sound subroutine clucks
  - then calls the horse’s sound
    - which calls the pig’s
      - which calls the cow’s to finish the verse!
Subroutines So Far

• Can be used to gather up repeated code in one place.
• Can be deeply nested to capture structure when necessary.
• Next, parameters greatly increase the power of the subroutine idea...

Near Miss...

Magical Mystery Tour (Beatles)

Roll up, roll up for the mystery tour.
Roll up, roll up for the mystery tour.
Roll up, roll up for the mystery tour.
Roll up, roll up for the mystery tour. The magical mystery tour is ______ to take you away, ______ to take you away.

Roll up, roll up for the mystery tour.
Roll up, roll up for the mystery tour.
Roll up, roll up for the mystery tour. The magical mystery tour is ______ to take you away.

Roll up, roll up for the mystery tour.
Roll up, roll up for the mystery tour.
The magical mystery tour is ______ to take you away.

• Verse structure is nearly repetitive. Can’t quite define a single subroutine that covers all three.
• If we could fill in the blank, we could reuse the same routine...
“Say Word” Subroutine

- Variable “word” keeps track of which word it should actually say.

In The Verse...

- Plug in the word at the proper time.
Main Song

- Do each verse with a different setting of “word”.
- Then, sing the conclusion.

Recursion...

- We saw in McDonald and other examples that subroutines can call other subroutines.
- Sometimes it is useful for a subroutine to call itself.
- This is called recursion.
- First, some song examples, then more general...
A Recursive Song!

• Sing a verse
• Update bottles
• Sing the next verse

Everyday Recursion

• Some people think recursion is scary, but it’s all around us: language, nature, toys, music, family trees, mathematical expressions.

• If you like self-reference, you’ll love recursion!
Recursion Gone Wrong

• Featured in “Lambchop’s Play-along”
• Canceled.

This is ‘The Song That Doesn't End'
Yes it goes on, and on my friend
Some people, started singing it
not knowing what it was
And they’ll just keep on singing it
forever just because...