

## 4. DEBUGGING

### How to Find a Bug

#### Debugging Approaches

There are two parts to debugging, the locating, and fixing, of bugs. We'll look at locating the bugs first, so if the RegEx (or RegExes) runs but doesn't give us the results we are expecting, there is some bug in the RegEx (or RegExes) that we need to find (we should also check the rest of the program). The computer is only doing what it is told, so there must be a wrong instruction somewhere. There are a number of debugging approaches that can be taken to find that instruction:

- **Brute Force Approach:** This is probably the most common approach to debugging, and it typically involves splitting the Regular Expression into parts from the start, and running each part separately to make sure we understand what it is doing. There are also tools that can be used in this approach, these include both tracing tools and debugging tools, e.g. <https://regex101.com/>
- **Backtracking Approach:** The backtracking approach is exactly what it sounds like, you start at the end of the RegEx, manually reviewing each part of the RegEx, or each metacharacter in the RegEx to see if it is correctly written, until the incorrect instruction is found.
- **Cause Elimination Approach:** This approach involves creating a list of possible causes (or hypothesis) for the bug, and initial tests are carried out to eliminate each hypothesis. Of the ones that cannot be eliminated in the initial testing, further tests are carried out to eliminate more and more hypotheses, until there is only one cause left. The bug is then located.

#### One More Thing....

This may be just me, but when I'm trying to debug a program, and I don't feel like I'm making progress; sometimes if I recite a verse of poetry, or part of a song, and I do that a couple of times, and it gives me the fortitude to continue and succeed. The two verses below are the ones I most commonly use.

*There's nothing you can do that can't be done;  
Nothing you can sing that can't be sung;  
Nothing you can say, but you can learn how to play the game;  
It's easy.*

From the song "All You Need Is Love" by John Lennon and Paul McCartney (1967)

*Great bugs have little bugs upon their backs to bite 'em,  
And little bugs have lesser bugs, and so ad infinitum.  
And the great bugs themselves, in turn, have greater bugs to go on;  
While these again have greater still, and greater still, and so on.*

"Siphonaptera" from Augustus De Morgan's *A Budget of Paradoxes* (1872)