Using the definition,

$$\gcd(b,c) = d$$

such that $d|a; d|b$ and if $f|a, f|b$ then $f|d$

So

$$\gcd(a, gcd(b,c)) = \gcd(a,d) = e$$

Again, using the definition, $e|a$ and $e|d$. Since $d|a$ and $d|b$ we get $e|a$ and $e|b$. So $e|a; e|b; e|c$.

Next, if $f|a$ and $f|d$ then $f|e$. Using the fact $d|b$ and $d|c$ then we have implication

$$f|a, f|b, f|c \Rightarrow f|e$$

So

$$\gcd(a, gcd(b,c)) = \gcd\big(a,(b,c)\big) = \gcd(a,b,c)$$

Using the symmetry

$$\gcd(a,b,c) = \gcd\big(a,(b,c)\big) = \gcd\big((a,b),c\big) = \gcd\big((a,c),b\big)$$