# THE BINOMIAL THEOREM

## Pascal's Triangle and the Binomial Expansion

Consider the following binomial expansions:

$$(p + q)^0 = 1,$$
$$(p + q)^1 = p + q,$$
$$(p + q)^2 = p^2 + 2pq + q^2,$$
$$(p + q)^3 = p^3 + 3p^2q + 3pq^2 + q^3,$$
$$(p + q)^4 = p^4 + 4p^3q + 6p^2q^2 + 4pq^3 + q^4,$$
$$(p + q)^5 = p^5 + 5p^4q + 10p^3q^2 + 10p^2q^3 + 5pq^4 + q^5.$$

The generic expansion is in the form of

$$(p + q)^n = p^n + np^{n-1}q + \frac{n(n-1)}{2}p^{n-2}q^2 + \frac{n(n-1)(n-2)}{3!}p^{n-3}q^3 +$$
$$\cdots + \frac{n(n-1)\cdots(n-r+1)}{r!}p^{n-r}q^r + \cdots$$
$$+ \frac{n(n-1)(n-2)}{3!}p^3q^{n-3} + \frac{n(n-1)}{2}p^2q^{n-2} + npq^{n-1} + p^n.$$

In a tidier notation, this becomes

$$(p + q)^n = \sum_{x=0}^{n} \frac{n!}{(n-x)!x!}p^x q^{n-x}.$$

We can find the coefficient of the binomial expansions of successive degrees by the simple device known as Pascal's triangle:

```
            1
          1   1
        1   2   1
      1   3   3   1
    1   4   6   4   1
  1   5  10  10   5   1
```

The numbers in each row but the first are obtained by adding two adjacent numbers in the row above. The rule is true even for the units which border the triangle if we suppose that there are some invisible zeros extending indefinitely on either side of each row.

Instead of relying merely upon observation to establish the formula for the binomial expansion, we should prefer to derive the formula by algebraic methods. Before

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