

# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---

$$k \cdot b(k) = k \cdot \binom{n}{k} p^k q^{n-k}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---

$$k \cdot b(k) = k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---

$$\begin{aligned} k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\ &= \frac{n(n-1)(n-2) \cdots (n-k+1)}{(k-1)!} p^k q^{n-k} \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---

$$\begin{aligned} k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\ &= \overset{\leftarrow}{\boxed{n}} \frac{(n-1)(n-2) \cdots (n-k+1)}{(k-1)!} p^k q^{n-k} \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---

$$\begin{aligned} k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\ &= \overbrace{n(n-1)(n-2) \cdots (n-k+1)}^{((n-1)-(k-1)+1)} p^k q^{n-k} \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$


---

$$\begin{aligned} k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\ &= \frac{\overbrace{n(n-1)(n-2) \cdots (n-k+1)}^{((n-1)-(k-1)+1)} p^{\overbrace{k}^{p \cdot p^{k-1}}} q^{n-k}}{(k-1)!} \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k;p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$

---

$$\begin{aligned} k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\ &= \frac{\overbrace{n(n-1)(n-2) \cdots (n-k+1)}^{((n-1)-(k-1)+1)}}{(k-1)!} \overbrace{p^k q^{n-k}}^{p \cdot p^{k-1} q^{(n-1)-(k-1)}} \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$


---

$$\begin{aligned}
 k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\
 &= \frac{\boxed{n} (n-1)(n-2) \cdots \boxed{(n-k+1)}}{(k-1)!} \boxed{p^k} \boxed{q^{n-k}} \quad \begin{array}{l} \text{((n-1)-(k-1)+1)} \\ \text{p} \cdot \text{p}^{k-1} \end{array} q^{(n-1)-(k-1)} \\
 &= np \cdot \frac{(n-1)(n-2) \cdots ((n-1)-(k-1)+1)}{(k-1)!} p^{k-1} q^{(n-1)-(k-1)}
 \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$


---

$$\begin{aligned}
 k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\
 &= \frac{\overbrace{n(n-1)(n-2) \cdots (n-k+1)}^{((n-1)-(k-1)+1)} p^{\overbrace{k}^{p \cdot p^{k-1}}} q^{n-k}}{(k-1)!} q^{(n-1)-(k-1)} \\
 &= np \cdot \frac{(n-1)(n-2) \cdots ((n-1)-(k-1)+1)}{(k-1)!} p^{k-1} q^{(n-1)-(k-1)} \\
 &= np \cdot \binom{n-1}{k-1} p^{k-1} q^{(n-1)-(k-1)}
 \end{aligned}$$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$


---

$$\begin{aligned}
 k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\
 &= \frac{\overbrace{n(n-1)(n-2) \cdots (n-k+1)}^{((n-1)-(k-1)+1)} \overbrace{p^k q^{n-k}}^{p \cdot p^{k-1} q^{(n-1)-(k-1)}}}{(k-1)!} \\
 &= np \cdot \frac{(n-1)(n-2) \cdots ((n-1)-(k-1)+1)}{(k-1)!} p^{k-1} q^{(n-1)-(k-1)} \\
 &= np \cdot \binom{n-1}{k-1} p^{k-1} q^{(n-1)-(k-1)}
 \end{aligned}$$

The basic binomial identity:  $k \cdot b_n(k; p) = np \cdot b_{n-1}(k-1; p)$



# A little algebraic spadework

$$b(k) = b_n(k; p) = \binom{n}{k} p^k q^{n-k} \quad (k = 0, 1, \dots, n)$$

$$\mu = 0 \cdot b(0) + 1 \cdot b(1) + \dots + k \cdot b(k) + \dots + n \cdot b(n)$$


---

$$\begin{aligned}
 k \cdot b(k) &= k \cdot \binom{n}{k} p^k q^{n-k} = k \cdot \frac{n(n-1)(n-2) \cdots (n-k+1)}{k!} p^k q^{n-k} \\
 &= \frac{\overbrace{n(n-1)(n-2) \cdots (n-k+1)}^{((n-1)-(k-1)+1)}}{(k-1)!} \overbrace{p^k q^{n-k}}^{p \cdot p^{k-1} q^{(n-1)-(k-1)}} \\
 &= np \cdot \frac{(n-1)(n-2) \cdots ((n-1)-(k-1)+1)}{(k-1)!} p^{k-1} q^{(n-1)-(k-1)} \\
 &= np \cdot \binom{n-1}{k-1} p^{k-1} q^{(n-1)-(k-1)}
 \end{aligned}$$

The basic binomial identity:  $k \cdot b_n(k; p) = np \cdot b_{n-1}(k-1; p)$

$$(k-1) \cdot b_{n-1}(k-1; p) = (n-1)p \cdot b_{n-2}(k-2; p)$$