Brute Force Strengths and Weaknesses

- **Strengths**
  - wide applicability
  - simplicity
  - yields reasonable algorithms for some important problems (e.g., matrix multiplication, sorting, searching, string matching)

- **Weaknesses**
  - rarely yields efficient algorithms
  - some brute-force algorithms are unacceptably slow
  - not as constructive as some other design techniques

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**Divide-and-Conquer**

[Diagram of divide-and-conquer process]

**FIGURE 4.1** Divide-and-conquer technique (typical case)
Theorem (Master Theorem):
Let $T(n)$ be an eventually nondecreasing function that satisfies the recurrence

$$T(n) = aT(n/b) + f(n) \text{ for } n = b^k, \ k = 1, 2, \ldots$$
$$T(1) = c$$

where $a \geq 1$, $b \geq 2$, $c > 0$. If $f(n) \in \Theta(n^d)$ where $d \geq 0$, then

$$T(n) \in \begin{cases} 
\Theta(n^d) & \text{if } a < b^d \\
\Theta(n^d \log n) & \text{if } a = b^d \\
\Theta(n^{\log_b a}) & \text{if } a > b^d 
\end{cases}$$

Example: summation
Mergesort

1) Split array A[0..n-1] in two about equal halves and make copies of each half in arrays B and C
2) Sort arrays B and C recursively
3) Merge sorted arrays B and C into array A
   a) copy smallest element from B or C to A
   b) once B or C is processed, copy the remaining unprocessed elements from the other array into A.

ALGORITHM Mergesort(A[0..n-1])

//Sorts array A[0..n-1] by recursive mergesort
//Input: An array A[0..n-1] of orderable elements
//Output: Array A[0..n-1] sorted in nondecreasing order

if n > 1
    copy A[0..\[n/2\]-1] to B[0..\[n/2\]-1]
    copy A[\[n/2\]..n-1] to C[0.. \[n/2\] -1]

Mergesort(B[0.. \[n/2\] -1])
Mergesort(C[0.. \[n/2\] -1])
Merge(B, C, A)
ALGORITHM Merge(B[0..p-1], C[0..q-1], A[0..p+q-1])

//Merges two sorted arrays into one sorted array
//Input: Arrays B[0..p-1] and C[0..q-1] both sorted
//Output: Sorted array A[0..p+q-1] of the elements of B and C

i ← 0; j ← 0; k ← 0
while i < p and j < q do
    if B[i] ≤ C[j]
        A[k] ← B[i]; i ← i + 1
    else
        A[k] ← C[j]; j ← j + 1
    k ← k + 1
if i = p
    copy C[j..q-1] to A[k..p+q-1]
else
    copy B[i..p-1] to A[k..p+q-1]
Analysis of Mergesort

• All cases have same efficiency: $\Theta(n \log n)$

• Side Note: Number of comparisons in the worst case is close to theoretical minimum for comparison-based sorting:

$$\left\lfloor \log_2 n! \right\rfloor \approx n \log_2 n - 1.44n$$

• Space requirement: $\Theta(n)$
  • version without this requirements exist, but are more costly
  • Can be implemented without recursion (bottom-up)