Stream: $\sigma =< a_1, a_2, ..., a_m >$, token $a_i \in U = [n]$.
Goal: process σ using space s st $s << m \wedge s << n$, $s = O(\min(m, n))$, pref $s = O(\log m + \log n)$.
Sometimes best $s = polylog(\min(m, n))$, $polylog = O((\log(g(n))^c)$ for $c > 0$.
Streams can only be access in sequence.
Multiplicative condition: Let $A(\sigma)$ be random stram alg A on σ: Let ϕ be target function. A is an ϵ, δ-approx alg of ϕ if

$$\mathbf{Pr}[|\frac{A(\sigma)}{\phi(\sigma)} - 1| > \epsilon] \leq \delta$$

To strong a condition when $\phi(\sigma)$ has values close to zero.

Additive-approx: (ϵ, δ)-additative-approx-alg A of ϕ if

$$\mathbf{Pr}[|A(\sigma) - \phi(\sigma)|] \leq \sigma$$

Often instrested in statistical properties of multiset in σ. Let vector $\vec{F} = (f_1, ..f_n)^T$, $f_j = |\{i : a_i = j\}|$.
So $\phi(\vec{F})$ target. $\vec{F}$ frequency vector.
Turnstile model: $\sigma : [n] \times \{-L, ..., L\}$ so $f_j \sum_{|\{i:a_i=j\}|} l_i$. Redefined m to max number tokens in multiset $\|\vec{F}\|_1 \leq m$.
Strict turnstile model: $\vec{F} \geq 0$
Cash register model: $\forall i.l_i > 0$

1 Frequency Problem

Majority problem: if $\exists j : f_j > m/2$, then output j else null. Frequency problem: For some k, output $\{j : f_j > m/k\}$
Frequency-estimateion problem: For stream σ produce structure that can estimate $\hat{f}_a$ for freq f_a for $a \in [n]$.
Misra-Gries Alg: Takes param k (same as freq problem). Maintain associative array, fx bbt

```
Process j:
  If j in keys(A) then
    A[j] <- A[j]+1
  else if |keys(A)| < k -1 then
    A[j] <- 1
  else
    foreach l in keys(A)
      A[l] <- A[l] - 1
      if A[l] = 0 then remove l
  output: f^_a = A[a] if keys(a) else 0
```

When $A[j]$ decr then we decr k-1 other counters $\Rightarrow$ decr witnessed (applied to) k tokens $\Rightarrow \leq m/k$ decrs as $|\sigma| = m$, therefore $\hat{f}_j \leq f_j - m/k$.