Scheduling (Part II)

Professor Travis Peters
CSCI 460 Operating Systems
Fall 2019

Some slides & figures adapted from Stallings instructor resources.

Some slides adapted from Adam Bates's F'18 CS423 course @ UIUC
https://courses.engr.illinois.edu/cs423/sp2018/schedule.html

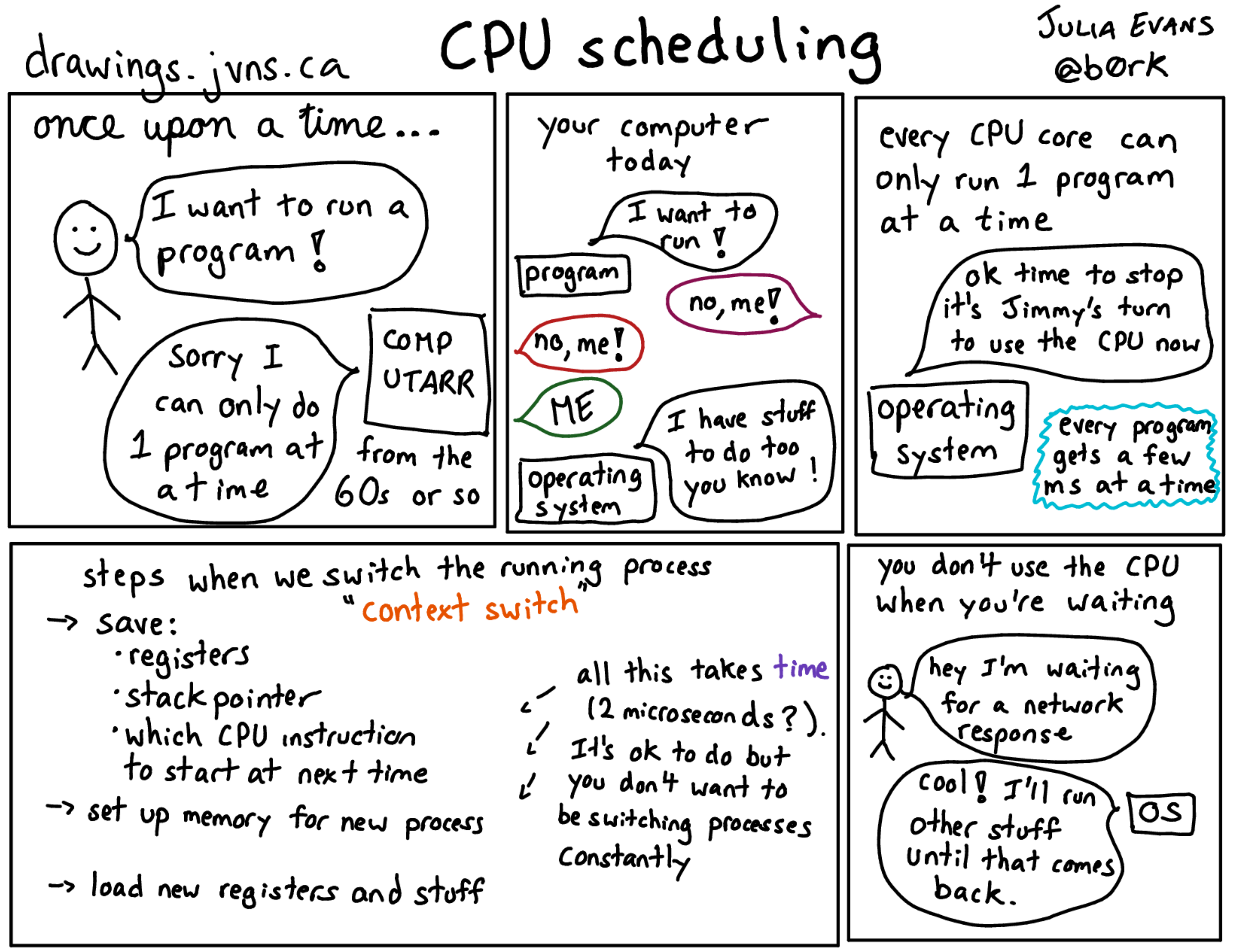
Goals for Today

Learning Objectives

- Explain the differences among long-, medium-, and short-term scheduling.
- Assess the performance of different scheduling policies.
- Understand the scheduling technique used in traditional UNIX.

Announcements

- Programming Assignment 1 Due TONIGHT @10pm!
  - →*Please upload as a zipped folder… upload issue was fixed ;)*

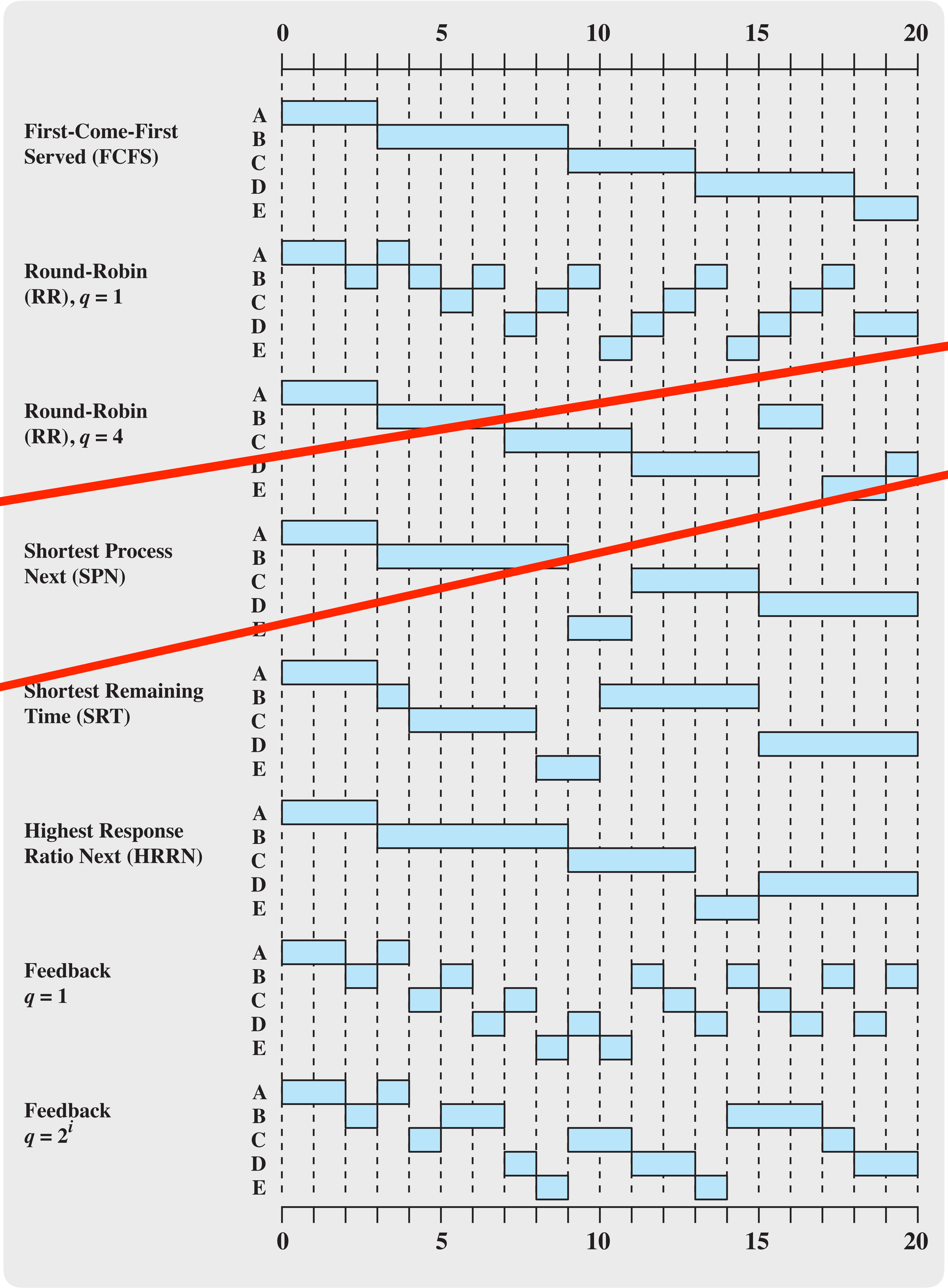


https://drawings.jvns.ca/scheduling/

Shortest Process Next (SPN)

Select the process with the shortest expected processing time, and do not preempt the process

- No preemption allowed…
- Process w/ shortest (expected) processing time is selected next
  - i.e., "short" processes cut to the head of a queue
- Need to know (or estimate) the required processing time…
  - How?
- **Q:** Potential issues?
- Some pretty undesirable characteristics…
  - Starvation for longer processes is possible (assuming shorter processes keep arriving)
  - Lacks preemption… not good for time-sharing systems



Process	A	B	C	D	E	
Arrival Time	0	2	4	6	8	
Service Time (T_s)	3	6	4	5	2	Mean
FCFS						
Finish Time	3	9	13	18	20	
Turnaround Time (T_r)	3	7	9	12	12	8.60
T_r/T_s	1.00	1.17	2.25	2.40	6.00	2.56
RR $q = 1$						
Finish Time	4	18	17	20	15	
Turnaround Time (T_r)	4	16	13	14	7	10.80
T_r/T_s	1.33	2.67	3.25	2.80	3.50	2.71
RR $q = 4$						
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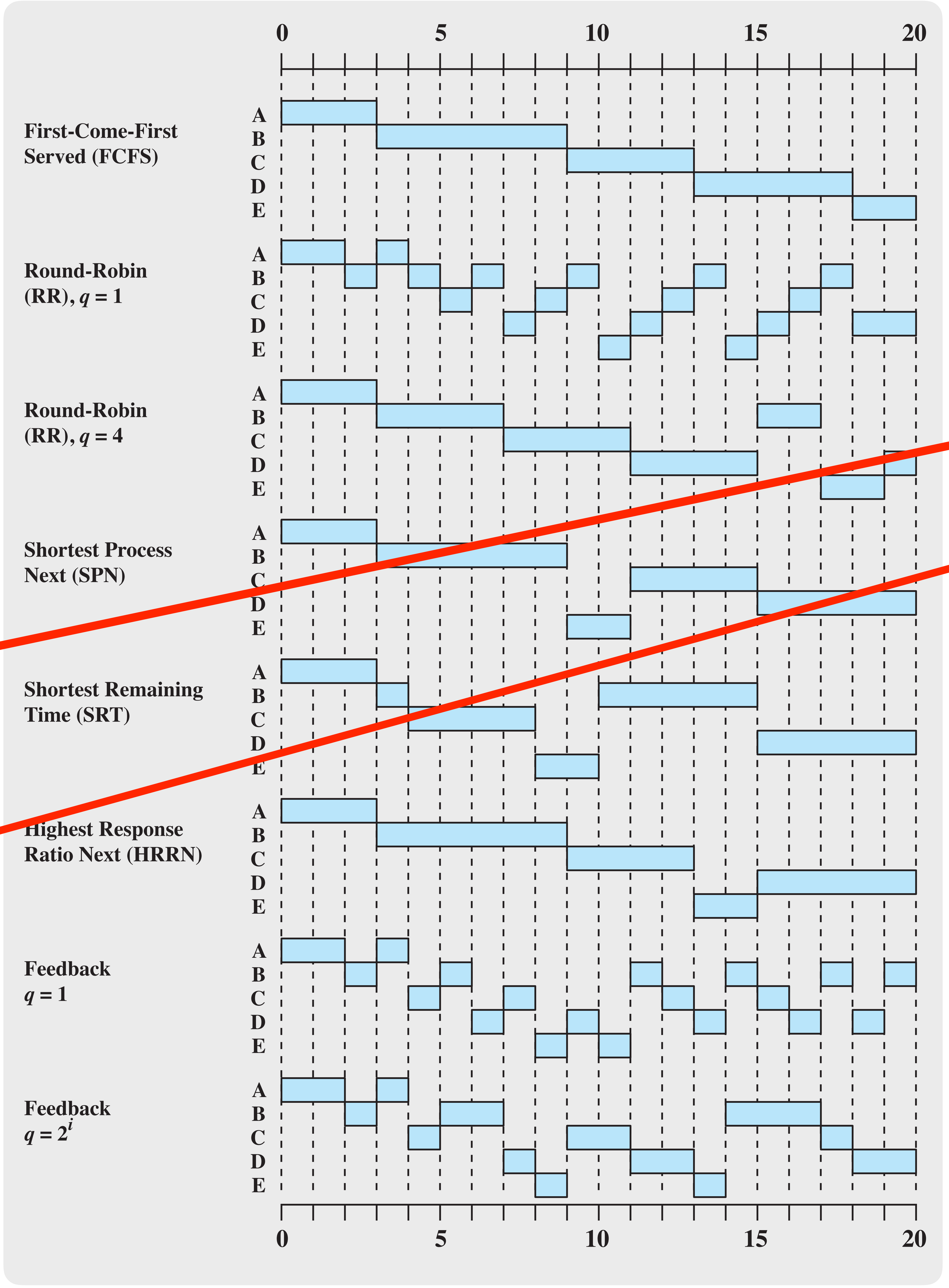
Shortest Remaining Time (SRT)

Select the process with the shortest expected remaining process time; preemption allowed

- Preemption allowed! *(a preemptive version of SPN)*
- Process w/ shortest (expected) ***remaining*** processing time is selected next
  - i.e., processes w/ less remaining time can preempt those w/ longer remaining times

- **Q:** Advantages? Disadvantages?

- ***Still…***
  - need to know (or estimate) the required processing time…
  - have a risk of starving longer-running processes…
  - incur overhead for recording service times, etc.
- ***BUT…***
  - SRT yields superior turnaround time as compared to SPN
    (i.e., a short task is given immediate preference to running a longer job)



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Highest Response Ratio Next (HRRN)

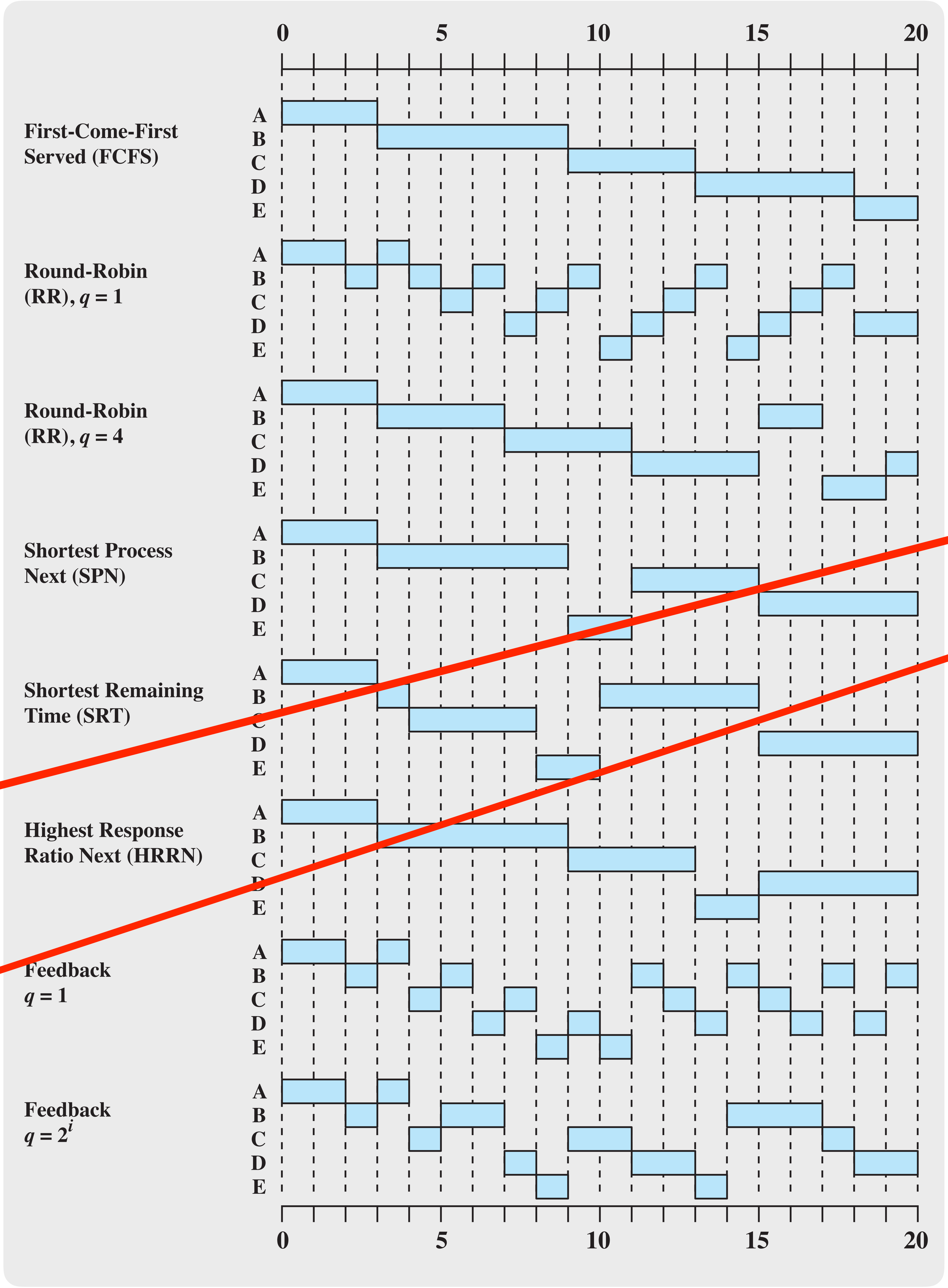
Base scheduling decision on an estimate of normalized turnaround time (TAT)

key
R = response ratio
w = time spent waiting
s = expected service time

- When the current process blocks
  → choose a ready process w/ the greatest ***normalized turnaround time (R)***

$$R = \frac{w + s}{s}$$

- Accounts for the age of the process!
  - shorter jobs are favored…
  - but an aging process without service increases the ratio, so a longer process will eventually get past competing shorter jobs.



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(Multilevel) Feedback

Establish a set of scheduling queues and allocate processes to queues based on execution history and other criteria

- SPN, SRT, HRRN are tricky — need reasonable estimates for execution time
- What if we instead "penalize" jobs that have been running longer?

If we can't get reliable measures of

time remaining to execute

let us focus on

time spent executing so far!

(Multilevel) Feedback

Establish a set of scheduling queues and allocate processes to queues based on execution history and other criteria

<u>The Idea:</u>

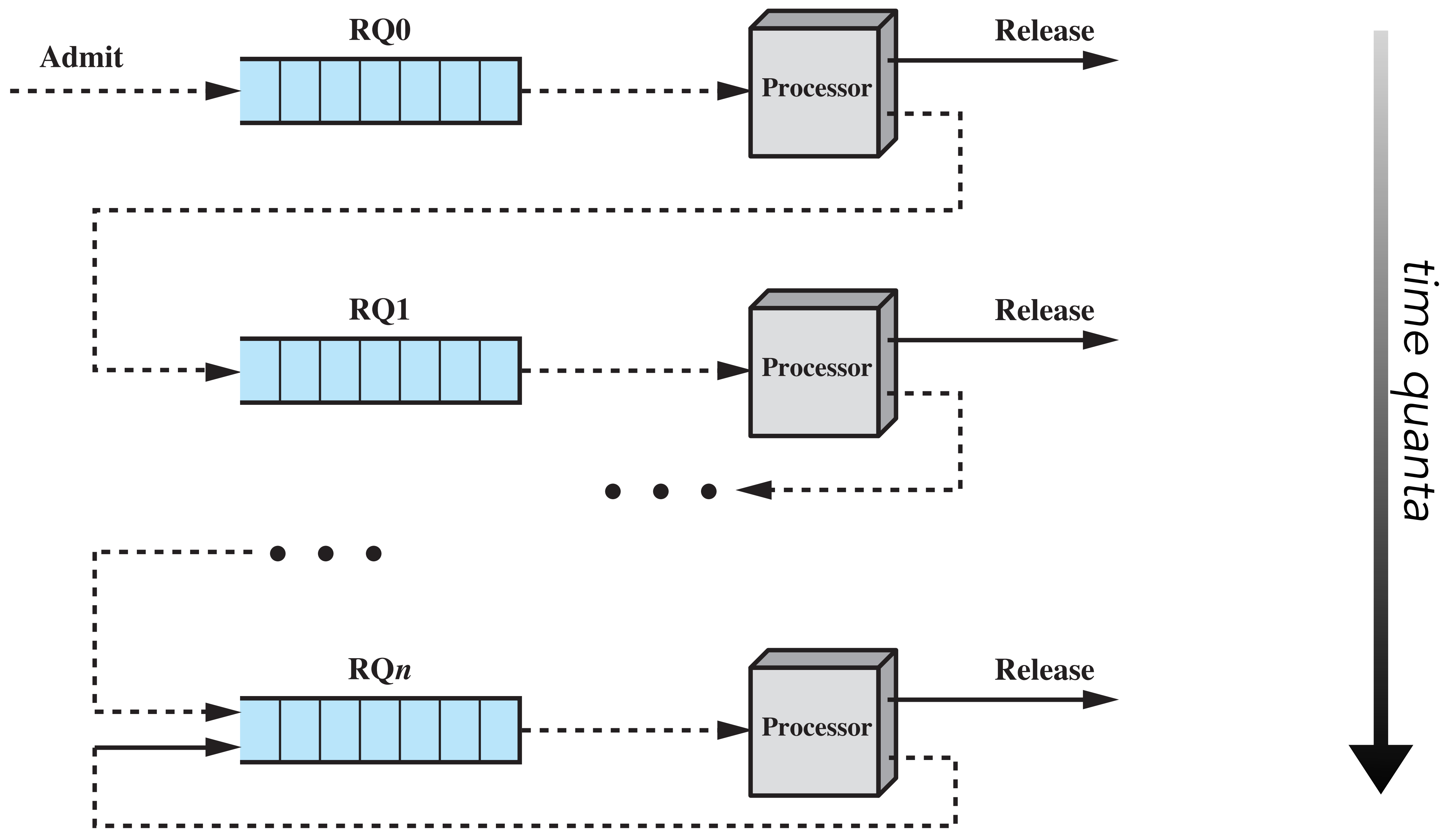
→ *Use some time quanta (re: [V]RR) to periodically interrupt a running process*

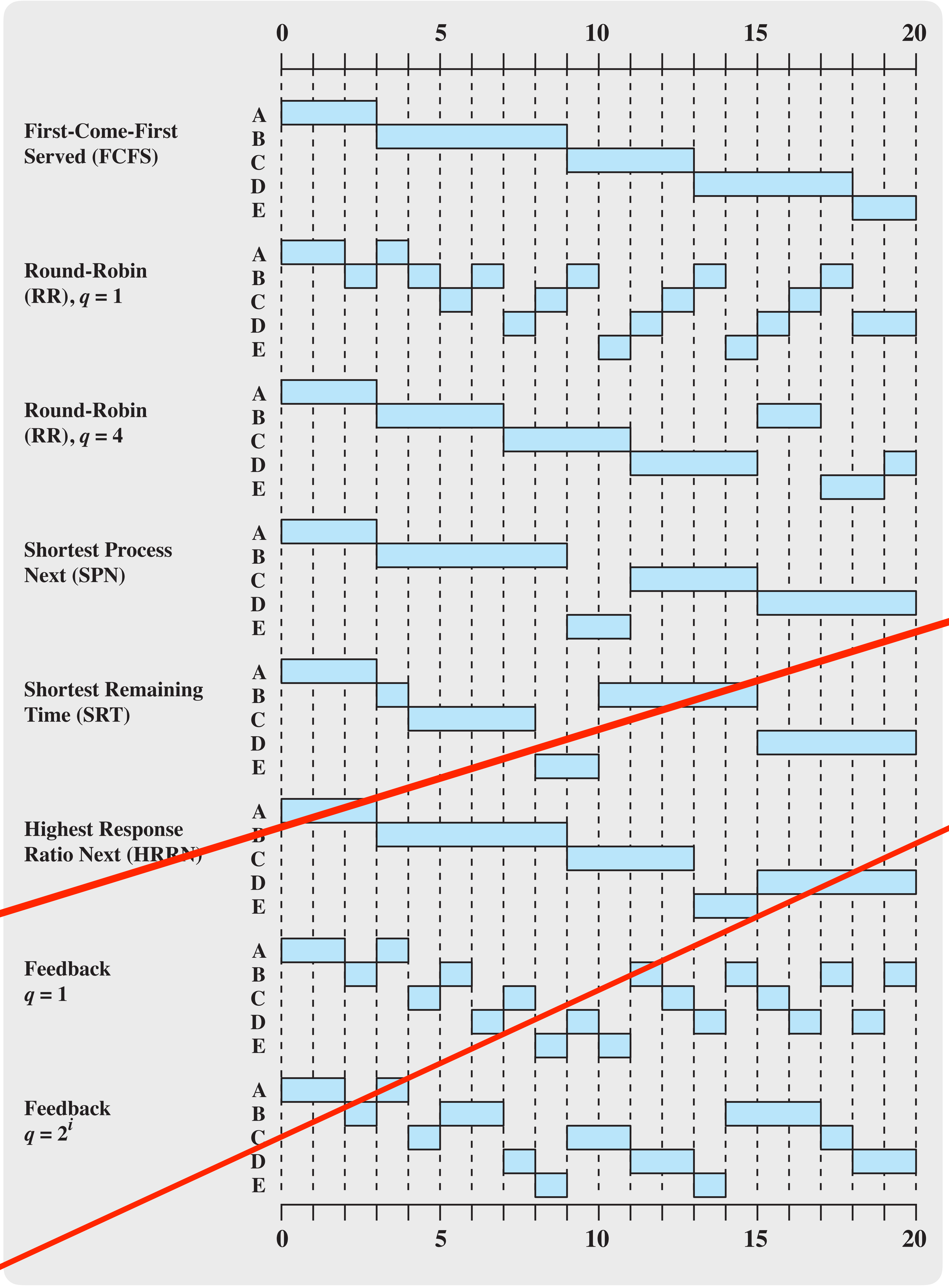
→ *"Demote" process to lower priority Q each time it returns to the RQ*

→ *Short processes still finish relatively quickly (few demotions)*

→ *Use FCFS in all Qs (except lowest-priority Q, which acts as RR; cannot demote any further)*

Any issues?





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So… which approach is best?

Performance Comparisons & General Take-Aways

- Difficult to develop closed analytic models for comparisons*

  → *All approaches (except RR and FCFS) depend on **expected service times**, which really complicates things*

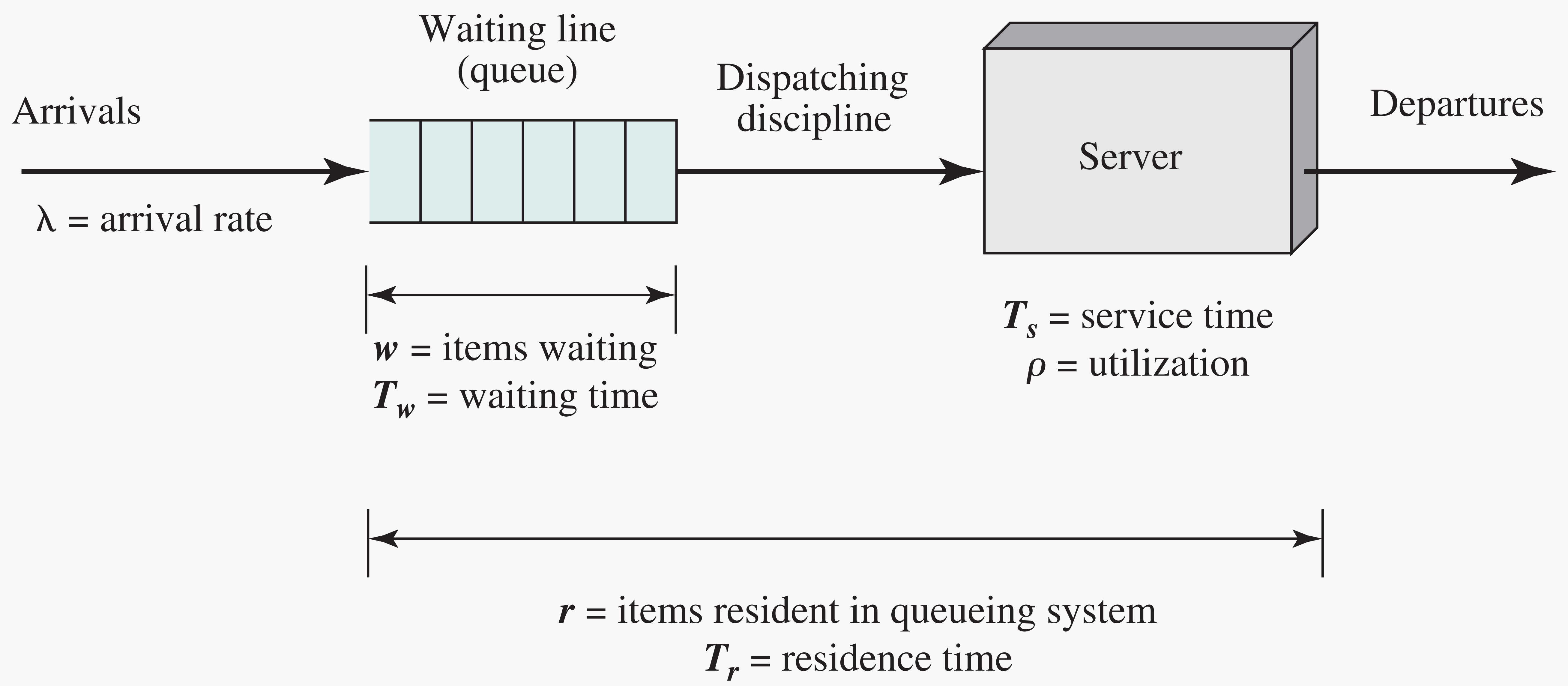
- Relative performance depends on a variety of factors
  - ***probability distribution*** of service times of processes
  - ***efficiency*** of scheduling mechanisms
  - ***efficiency*** of context switching mechanisms
  - ***demand*** on, and efficiency of, I/O subsystem(s)
  - …

Performance Comparisons & General Take-Aways (Queuing Analysis)

- Difficult to develop closed analytic models for comparisons*
  → *All approaches (except RR and FCFS) depend on* ***expected service times****, which really complicates things*
- Relative performance depends on a variety of factors
  - probability distribution of service times of processes
  - efficiency of scheduling mechanisms
  - efficiency of context switching mechanisms
  - demand on, and efficiency of, I/O subsystem(s)

- Enter ***Queueing Analysis***
  - Assume: Poisson arrivals
    → *random arrival times*
  - Assume: exponential service times
    → *more demand == longer service times*
  - Assume: priority-based scheduling…
    → *higher priority items served first*
    → *FCFS for items of equal priority*

Single-Server Queue Model

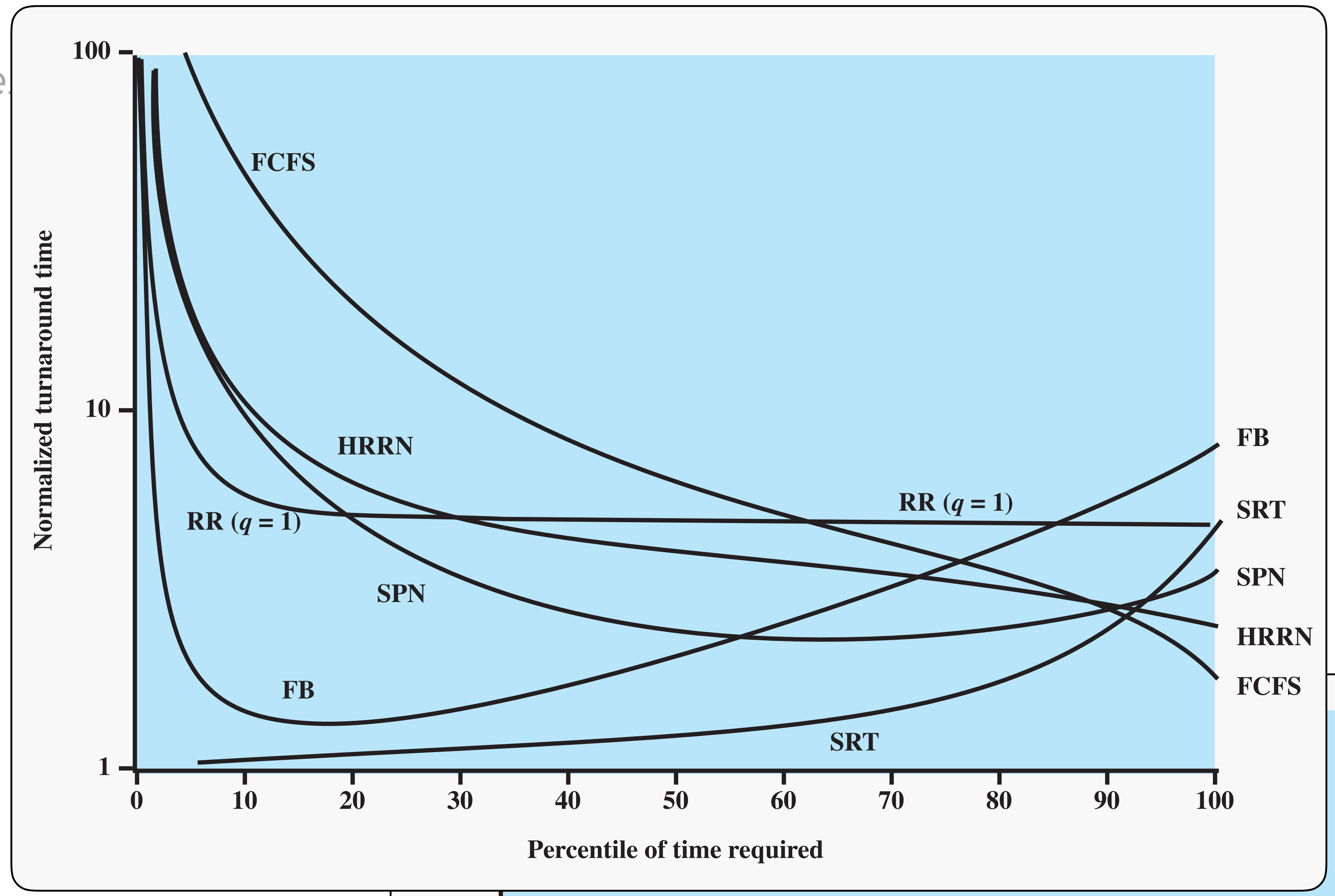


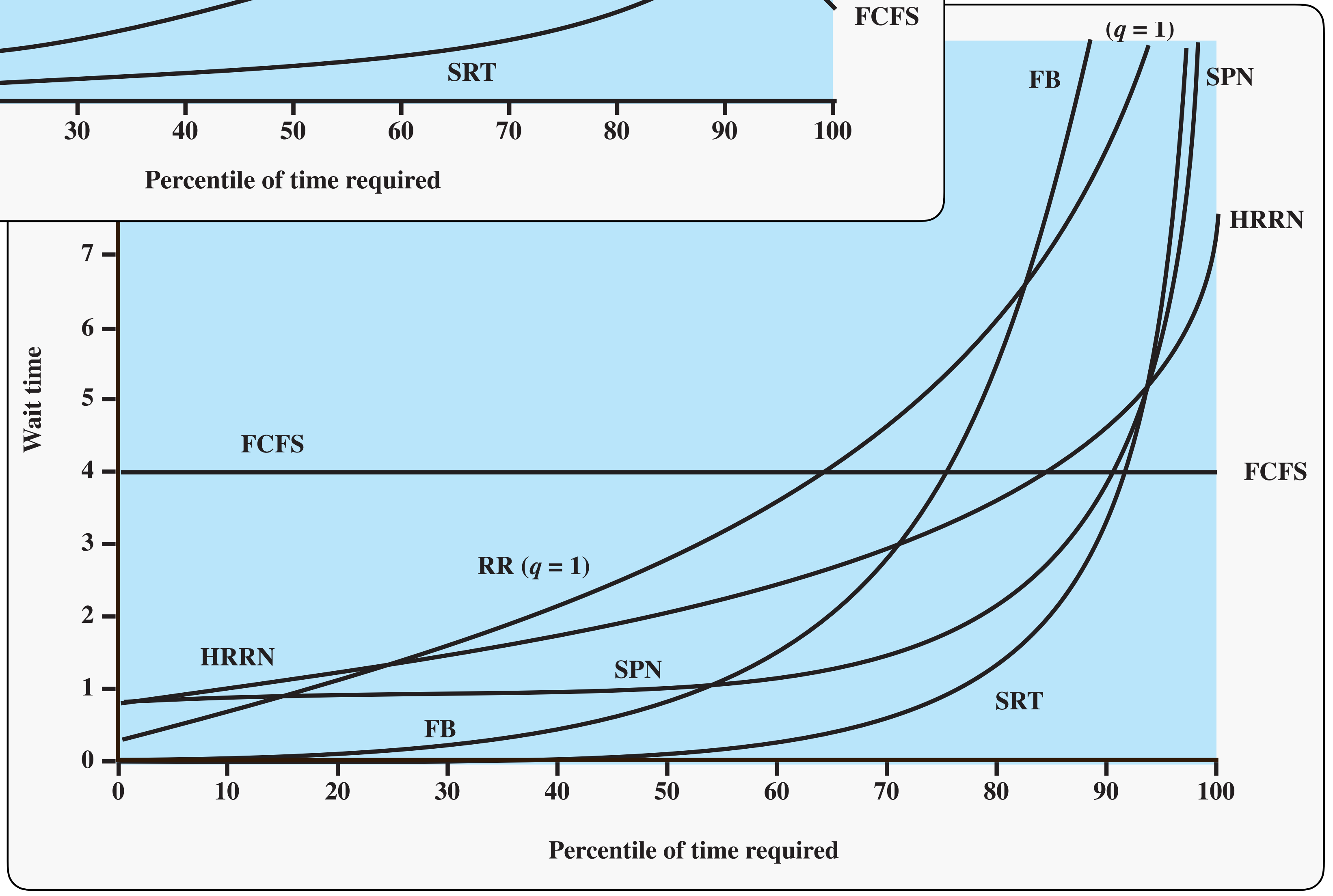
Extensions also exist for ***multiple servers*** *and* ***multiple queues***

Performance Comparisons & General Take-Aways (Simulations)

- Difficult to develop closed analytic models for comparisons*
  → *All approaches (except RR and FCFS) depend on **expected service times**, which really complicate*
- Relative performance depends on a variety of factors
  - probability distribution of service times of processes
  - efficiency of scheduling mechanisms
  - efficiency of context switching mechanisms
  - demand on, and efficiency of, I/O subsystem(s)

- Enter ***Simulation Modeling***
  - **Pros:** discrete event simulations allow a variety of models to be simulated & compared
    - Able to visualize direct comparisons between policies
    - Compare **wait times**, **normalized turnaround times**, …
  - **Cons:** results only really hold for a given "run"
    - a particular collection of processes…
    - a particular set of assumptions & constraints…





Fair-Share Scheduling

Establish a set of scheduling queues and allocate processes to queues based on execution history and other criteria

- Approaches so far all treat processes as a fairly homogeneous collection of ready-to-execute items
  - Many independent processes
  - Can be sub-divided by priority
  - Otherwise, treated the same
- **Q:** Can we see a potential issue with this?
  - What if there are 2 users, Alice and Bob, where each run 1 "app"
  - … and Alice's app is made up of 1 process
  - … and Bob's app is made up of 100 processes
- Fair-Share Scheduling
  - assign each user/group a "share" of the processor
  - monitor resource usage…
    - → give ***fewer resources*** to user/group that has had ***more than their fair share***
    - → give ***more resources*** to user/group that has had ***less than their fair share***

Note:
"fair-share"
doesn't necessarily mean
"equal share"

Fair-Share Scheduling *(example)*

Time	Process A Priority	Process A Process CPU count	Process A Group CPU count	Process B Priority	Process B Process CPU count	Process B Group CPU count	Process C Priority	Process C Process CPU count	Process C Group CPU count
0	60	0 1 2 • • 60	0 1 2 • • 60	60	0	0	60	0	0
1	90	30	30	60	0 1 2 • • 60	0 1 2 • • 60	60	0	0 1 2 • • 60
2	74	15 16 17 • • 75	15 16 17 • • 75	90	30	30	75	0	30
3	96	37	37	74	15	15 16 17 • • 75	67	0 1 2 • • 60	15 16 17 • • 75
4	78	18 19 20 • • 78	18 19 20 • • 78	81	7	37	93	30	37
5	98	39	39	70	3	18	76	15	18

Group 1 (Process A) — Group 2 (Process B, Process C)

Colored rectangle represents executing process