

FINANCIAL MARKET INFRASTRUCTURE

EXCHANGE CONCEPTS

PART I – Foundation & History

A conceptual guide to financial exchange architecture, order books & matching engines.

46	273	10	NO
CHAPTERS	GLOSSARY TERMS	REAL EXCHANGES	MATHS REQUIRED

J. Persson

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Exchange Concepts

An Introduction for Beginners

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Preface to the Second Edition

This book is still for the same person: the developer who gets dropped into an exchange codebase full of words like “NBBO”, “LULD”, “implied in/out”, “ATC”, “SIP”, “MMP”, and quietly wonders whether they have accidentally joined a cult. You have not. You have joined a domain with very old vocabulary, very modern latency budgets, and very expensive failure modes.

The first edition focused on giving the reader a map. This second edition keeps the same promise, almost no code-first deep dives, no equations for their own sake, just concepts that make the system legible, but the map is now wider, denser, and more practical. Compared with the first edition, this edition adds well over a thousand lines of new material and rewrites key chapters that were a bit too brief in the first pass where obviously my aspiration to keep it short sometimes conflicted with the need for completeness and understandability. Some pseudo-code has in addition been added where it helps clarify the mechanics, but the focus is still on concepts, not implementation. The goal is still to give you a mental model that lets you reason about the system, not just translate jargon.

The largest expansion is in the implied-orders material, which has been rebuilt from a short overview into two full chapters placed at the end of Part II, once the order book and the matching engine are familiar. The first is a complete walkthrough: the spread sign convention, a vector model from which every implied price formula follows, quantity, depth and priority rules, tick alignment, market-data publication, a first-generation algorithm, engineering invariants, and self-check exercises with worked solutions. The second follows chains of implied orders across many contract months and shows why every venue must limit how far implication is allowed to reach. The order-book chapter has also been expanded from concept to implementation shape: cache behavior, memory layout, single-threaded matching partitions, pool allocation, and step-by-step insert/cancel/sweep mechanics, including determinism concerns.

Several missing bridge topics are also now included explicitly. Part I this time around closes with listing (including the part black-magic art of IPO valuation) and delisting mechanics (initial and continued standards, cure periods, reverse splits, voluntary delisting, direct listings, and SPAC pathways). Part II adds round-lot vs odd-lot treatment and a dedicated tick-size chapter (Rule 612, historical fraction pricing, Tick Size Pilot, and midpoint rounding). The auction material has been upgraded with auction-only order types, opening/closing cross mechanics, and manipulation-at-the-close context.

Beyond core matching, this edition also adds the operational and structural topics developers eventually run into: benchmark integrity (LIBOR and FX fix case studies), trade busting and clearly erroneous handling, conformance testing and onboarding drift, market-data economics (SIP vs proprietary feeds, locked/crossed markets), fixed-income microstructure, crypto venue differences, and options expiry mechanics (exercise, assignment, settlement type, and pin risk).

So yes, the document is longer now. That is deliberate. The first edition tried to keep every section short; this one tries to keep every section useful when things get messy in production. If the first edition was the “day one” guide, this one aims to be the “month six” guide, the point where you are no longer asking what a term means, but why the system was designed that way and what breaks if it is wrong.

As before, this is an introduction, not a rulebook. Exchange rulebooks and venue technical specifications remain the final authority. But if this second edition helps you move from terminology to reasoning faster, it has done its job. The reference section includes the publicly available reference material many details in this books draws from to be as exact as possible.

Reasonable efforts have been made to ensure accuracy, but, it would be foolish of me to believe that I during some late night/early morning while editing this book didn't swap some bid/ask columns or simply forgot a whole section I had in my notes or my mind.

Enjoy the pleasure of finding things out and the triumph of being sure that the author was proveable wrong! So, any typos, missing signs, bad explanations/grammar or faults otherwise, are mine and mine alone. I have no-one to blame!

If you find any mistakes or have other suggestions, please let me know at *johan162@gmail.com*. I genuinely appreciate it.

Johan Persson, Second Edition, Autumn 2026, Järnboås Socken

Preface to the First Edition

This is a book for anyone who finds themselves having been asked to work on a financial exchange system, and yet, has no financial background. Scary. The codebase is full of words like "bid," "ask," "FOK," "the book," "OCO," "circuit breaker," "drop copy," and "kill switch," and many more. These are not arbitrary names; each one represents a concept that evolved over decades of real-world market operation, regulation, and hard-won lessons about what can go wrong when large amounts of money change hands at high speed. You just happened to be "unlucky" enough to start when all these terms have already been defined. Had you instead started 50-ish years ago the terms did not yet exist and you would have seen them come to life organically.

My goal with this book is simple: give you the conceptual vocabulary so that when someone says "GW01 submitted a GTC iceberg order that triggered a circuit breaker halt," you nod instead of panic. No code. No math. Just the map of the territory your code inhabits.

I have tried to keep things brief: each concept gets only as much space as it needs to be useful, and not a page more. Where I have necessarily oversimplified, you will find pointers at the end to the proper academic treatments (hundreds of pages of the hard stuff) for those rare evenings when you feel brave (or masochistic) enough to dive deeper. I make that promise with a clear conscience, because I spent rather too many evenings, and far too many weekends, working through the classic finance texts listed in the references, which served as the primary sources for this little book. If I am honest, this booklet is really nothing more than my own "lecture notes" from all that reading, tidied up and handed to you so you can skip the long way round. In the reference section you can find micro-reviews of all the books I used and taken inspiration from. You can also discover my own personal favourite!

This is an introduction, not a specification. Real exchanges are far more complex, and their official rulebooks are the final word. Think of this as the document I wish someone had handed me on day one I started to work in this world. I hope it helps you get up to speed faster than I did.

Reasonable efforts have been made to ensure accuracy, but as usual any remaining errors are entirely my fault. If you find mistakes or have suggestions, please let me know at *johan162@gmail.com* I genuinely appreciate it!

Johan Persson, First Edition, Winter 2025/2026, Järnboås Socken

PART I

Part I: Foundation: Markets, History, and Participants

Context, vocabulary, and the people that define exchange markets, the foundation you need before the mechanics make sense.

Historic Notes

In 1609, a Dutch merchant named Isaac Le Maire organised a consortium of traders to sell shares in the Dutch East India Company (VOC) that they did not yet own. The plan was to drive down the price and buy the shares back cheaply before delivery, the first recorded large-scale short selling operation in financial history. The scheme was brazen enough that the Dutch authorities issued an edict banning the practice the following year, in 1610. The ban failed. Le Maire was undaunted: he had grasped something fundamental about financial markets that would take regulators centuries to fully accept. Markets are not just places where things are bought and sold. They are environments in which participants constantly probe the rules, exploit information asymmetries, and invent instruments to express views that the market has never had to handle before. The job of exchange infrastructure, the order books, the matching engines, the risk controls, and the audit trails, is to provide a fair, stable, and trustworthy arena for all of this to happen, without breaking when the participants are clever, aggressive, or occasionally reckless.
Every section of this Part can be traced, directly or indirectly, back to what was happening in Amsterdam in 1602, when the VOC issued what are widely regarded as the world's first publicly traded shares. The primary market, the secondary market, the concept of equity, the vocabulary of long and short, the role of brokers, the need for a central marketplace, it was all there, in embryonic form, four centuries ago.
Part I builds that foundation.

Part Summary:

Build the conceptual base: why exchanges exist, how capital formation connects to secondary trading, how market language evolved, and who the key participants are in modern venues.

Learning Objectives:

- Explain the economic purpose of exchanges in the broader capital-raising cycle.
- Distinguish primary vs secondary markets and debt vs equity at a practical level.
- Use core market vocabulary confidently in historical and modern context.
- Identify major participant types and their incentives in real-world exchange ecosystems.

Content:

- Before the Exchange: How Companies Raise Capital
- What Is a Financial Exchange, and Why Does It Exist?
- The Language of the Market: A Short History
- The Participants
- A Brief Tour of Real-World Exchanges
- Listing and Delisting Mechanics

CHAPTER 1

Before the Exchange: How Companies Raise Capital

To understand why a financial exchange exists, you first need to understand why anyone bothers issuing shares in the first place. This section is a brief detour into basic corporate finance, the world your exchange is built to serve.

1.1 The Problem of Growth

Imagine a small software company. It has a product, a team, and paying customers, but it wants to grow: hire more engineers, open offices in new countries, and invest in research that will take three years to generate revenue. All of that costs money, far more money than the company currently earns in a month or a quarter.

Where does that money come from? There are three broad categories of answer, and real companies use all three at different stages of their lives.

1.2 Option 1: Retained Earnings (Self-Funding)

The simplest source of capital is the company's own profits. If the company earns more than it spends, it can save that surplus and invest it in growth. This is called **retained earnings**, profits "retained" in the business rather than distributed to owners.

Self-funding is attractive because it involves no outside parties and no obligations. The problem is that it is slow. If the opportunity is time-sensitive, a competitor is building the same product, or a market window is closing, waiting years to accumulate enough internal cash may mean losing the race. Most high-growth opportunities require more capital, faster, than retained earnings can provide.

1.3 Option 2: Debt, Loans and Bonds

The second option is to borrow money. Borrowed money must be repaid, with interest [3]. The cost of borrowing (the interest rate) depends on how creditworthy the borrower is: established, profitable companies with predictable revenues can borrow cheaply; young, risky startups may not be able to borrow at all, or only at very high interest rates.

Bank loans are the most familiar form of debt. A company borrows a sum from a bank and repays it over time. This works well for small amounts and short timeframes, but a single bank may not be willing, or able, to provide hundreds of millions of dollars to a single borrower.

Bonds solve the scale problem by spreading the borrowing across many lenders. A bond is a standardised piece of debt. A company issues a bond with a **face value** (say, $1,000), a **coupon rate** (say, 5% per year), and a **maturity date** (say, 10 years from now). The investor who buys the bond lends the company $1,000 today. In return, the company promises to pay $50 per year (5% of $1,000) as regular interest payments (these periodic payments are called **coupons**, named after the physical coupon slips investors used to cut off

and redeem before the digital age), and to repay the full $1,000 when the bond matures in 10 years.

A large company might issue millions of these bonds simultaneously, raising hundreds of millions of dollars from thousands of individual investors. Those investors later need to be able to sell their bonds if they want their money back before maturity, and so bonds, just like shares, trade on exchanges and electronic markets.

The key characteristic of debt: the company has an unconditional obligation to make the promised payments. If it cannot, it is in default, which can lead to bankruptcy proceedings. Bondholders are **creditors**: they have a legal claim against the company's assets. In a bankruptcy, creditors get paid before the company's owners.

1.4 Option 3: Equity, Selling Ownership

The third option is fundamentally different in character: instead of borrowing money and promising to repay it, the company sells a piece of itself.

Equity is ownership. When a company issues **shares** (also called **stock** in American English, or **equities** in market terminology), it is dividing ownership of the business into small, standardised units and selling those units to investors [3]. Each unit, each share, represents a proportional claim on the company's assets, earnings, and future.

Here is the important distinction from debt: **there is no promise of repayment**. If you buy a share in a company, the company does not promise to give your money back. It does not promise to pay you any specific amount at any specific time. What you receive instead is ownership.

What does ownership actually mean?

- **Residual claim on profits:** If the company earns a profit and its board of directors decides to distribute some of that profit to owners, shareholders receive their proportional share as a **dividend**. Dividends are not guaranteed, the board may decide to reinvest profits in the business instead. But shareholders are entitled to whatever is left over after all expenses and debts are paid. This "residual" or "leftover" claim is the defining characteristic of equity.
- **Capital appreciation:** If the company grows and becomes more valuable, each share becomes worth more. A shareholder who paid $10 for a share and sells it when the company is worth twice as much can sell at roughly $20, realising a **capital gain**. The theoretical upside of an equity position is unlimited, a share can appreciate many times over (Apple shares, adjusted for the company's five stock splits since its 1980 IPO at $22, have multiplied in value more than a thousand times). Compare this to a bond, where the return is capped at the promised coupon rate.
- **Voting rights:** Shares typically carry the right to vote on major corporate decisions, electing the board of directors, approving mergers and acquisitions, and other significant matters. Owning 51% of the shares means controlling a majority of votes, which is why "controlling stake" is a meaningful concept.
- **Limited liability:** If the company goes bankrupt, shareholders can lose the money they invested, but nothing more. They are not personally liable for the company's debts. This protection ("limited liability") is a fundamental feature of the modern corporation and one reason equity investment became widespread.
- **Market capitalisation (market cap):** The total market value of all a company's outstanding shares, calculated as share price multiplied by the total number of shares in existence. If Apple has approximately 15.4 billion shares outstanding and each trades at $190 (roughly its position in 2023), Apple's market cap is 15.4 billion $\times$ $190 $2.9 trillion [1]. Market cap is the most widely used shorthand for a company's size. When rankings refer to "the world's largest exchange by listed market cap," they are summing the market caps of every company listed there.

What does ownership mean for the company?

Issuing equity capital has an important advantage over debt: the company is not obligated to make regular payments, and there is no maturity date on which it must repay anything. This flexibility is why many high-growth companies prefer equity, they can invest in long-term projects without the burden of fixed interest payments.

The trade-off is **dilution**: selling shares means selling a portion of the company. The founders and early investors own a smaller fraction of the whole. If a founder owned 100% of a company worth $1 million and raises $250,000 by selling a 20% stake to new investors, the company is now worth $1.25 million ($1 million of existing business value plus the $250,000 cash just raised). The founder owns 80% of $1.25 million, still $1 million in absolute terms, but a smaller fraction of the whole. The investors own 20% of $1.25 million = $250,000, exactly what they paid. Managed carefully, dilution is acceptable; managed carelessly, founders can lose control of their own companies.

Common stock and preferred stock

In practice, not all shares are equal. Most retail investors hold **common stock** (called **ordinary shares** in UK and European markets), which carries voting rights and a residual claim on profits. **Preferred stock** (or **preference shares**) is a different class: typically no voting rights, but a higher-priority claim on dividends and assets in a liquidation. Preferred holders are paid before common stockholders, though still after bondholders. Venture capital investors almost always receive preferred stock in early-stage companies, giving them downside protection that common stockholders lack [3].

When a company IPOs, most preferred shares convert to common shares. For exchange system developers, the class distinction matters because instruments are classified, regulated, and referenced differently. When you see "AAPL" on an exchange, it refers specifically to Apple's common stock. Preferred shares, when a company lists them, trade under a separate ticker, typically the common ticker plus a series suffix (a hypothetical company "XYZ" might list its Series A preferred as "XYZ-PRA" or "XYZ.PR.A", depending on the data vendor's convention).

1.5 The Difference Between Debt and Equity

A useful mental model: when a company issues bonds, it is renting capital, borrowing it with the obligation to return it. When a company issues equity, it is selling a permanent stake, the investor becomes a partial owner, sharing in the future of the business.

The consequence:

	Debt (Bonds, Loans)	**Equity (Shares)**
Relationship to company	Lender / Creditor	Owner
Return	Fixed interest (coupon)	Variable (dividends + capital gains)
Repayment obligation	Yes, principal returned at maturity	No
Payment priority in bankruptcy	Paid first	Paid last (residual)
Risk to investor	Lower (predictable return)	Higher (no guaranteed return)
Dilutes ownership?	No	Yes
Upside potential	Capped (only the promised coupons)	Unlimited (shares in a successful company grow without limit)

A sophisticated investor builds a **portfolio** that mixes both: bonds for predictable income and capital preservation, equities for growth potential. The entire investment industry, pension funds, mutual funds, hedge funds, is built around managing this balance.

1.6 Going Public: The Initial Public Offering (IPO)

Early in a company's life, its shares are held by a small, private group: the founders, early employees (who often receive shares as part of their compensation), and **venture capital (VC) investors** who provided early funding in exchange for equity stakes. These shares are not available to the general public; the company is **private**.

At some point, usually when the company has proven its business model and needs a large infusion of capital for the next phase of growth, the company may choose to **go public**: to offer its shares for sale to anyone who wants to buy them. This event is called the **Initial Public Offering (IPO)**.

In an IPO:

1. The company works with **investment banks** to **underwrite** the offering. Underwriting means the banks agree to buy all the shares at a guaranteed price and immediately sell them on. This guarantee means the company receives its cash even if investor demand is weaker than expected. In practice, the banks first conduct a **roadshow**, a series of presentations to large institutional investors, to gauge demand and set the final price. They rarely actually get stuck holding the shares.
2. New shares are created and sold, with the proceeds going directly to the company (or to early investors who are "cashing out" their stakes).
3. The company's shares are listed on a stock exchange, NYSE, NASDAQ, LSE, or another regulated market.
4. From that moment, anyone can buy or sell the shares through the exchange.

Some of the largest IPOs in history by proceeds raised illustrate the scale: Saudi Aramco raised $25.6 billion in its December 2019 IPO on the Saudi Exchange (Tadawul), later increased to about $29.4 billion when the underwriters exercised their over-allotment option [1]; Alibaba raised $21.8 billion on NYSE in 2014, about $25 billion including the over-allotment [1]; Arm Holdings raised $4.9 billion on NASDAQ in September 2023 [1]. Each of these companies brought enormous new pools of capital onto public markets.

All of them were dwarfed in June 2026, when SpaceX listed on NASDAQ (ticker: SPCX) in the largest IPO by proceeds in history. Priced on 11 June at $135 per share, raising about $75 billion before the over-allotment, the offering implied a valuation of approximately $1.77 trillion; on its first trading day, 12 June, the stock closed at about $161, up roughly 19%, putting the company's market cap at about $2.1 trillion [Initial public offering of SpaceX, Wikipedia; CoinDesk, 11 June 2026]. Note that pricing a mega-IPO below $200 a share says nothing about the company's quality or size, it is purely a function of how many shares are outstanding relative to the total valuation, which the company and its underwriters can set almost arbitrarily by choosing the share count. (The historical "blue chip" usage described later in this document, where Oliver Gingold's 1923 Dow Jones column used $200 as a rough marker of a premium stock, was itself a nominal dollar figure of its era with no inflation adjustment; it was never a rule, and it says nothing about a company listing a century later.)

1.7 The Primary Market vs. the Secondary Market

This distinction is critical, and it is where the exchange fits in.

The **primary market** [3] is where new securities are created and sold for the first time. In an IPO, the company sells newly issued shares directly to investors, and the company receives the money. A bond issuance is also a primary market transaction, new bonds are created and the company receives the loan proceeds.

The **secondary market** [3] is where investors buy and sell securities that already exist, trading with each other rather than with the company. When you buy shares of Apple on NASDAQ today, Apple does not receive your money. The person selling you those shares receives it. Apple issued those shares long ago; they have been trading between investors ever since.

The stock exchange is among the primary venues of the secondary market. It is the most visible and regulated secondary market venue, but not the only one, OTC secondary trading, private transactions, and alternative trading systems also exist. For practical purposes in this document, when we say "the exchange," we mean a regulated, centralised lit venue; this is where the concepts of price-time priority, order books, and matching engines apply most directly.

This insight is important: the exchange does not help companies raise money directly. It helps investors trade securities they already own. But without the secondary market, the primary market would barely function. Here is why:

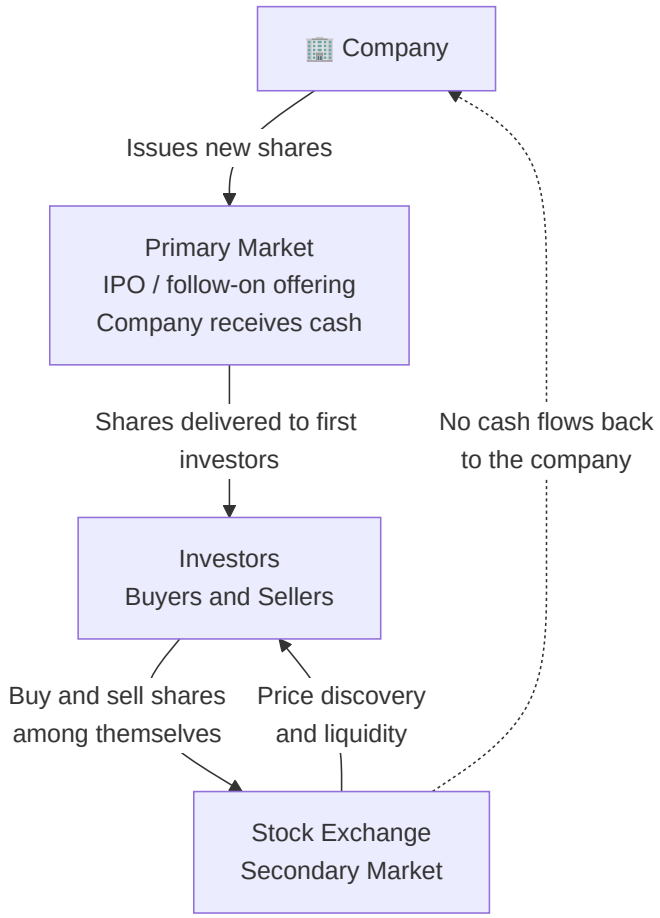
Who would invest in a company's IPO if they knew they could never sell their shares? Who would buy a 10-year bond if they had to hold it for exactly 10 years with no way out? The existence of a liquid secondary market, a place where you can sell whenever you want at a fair price, is what makes investors willing to

commit capital to companies in the first place. The exchange provides the exit. And the availability of an exit enables entry.

The primary market and secondary market form a virtuous cycle:

- Companies raise money in the primary market because investors are willing to commit capital.
- Investors commit capital because the secondary market lets them exit when they choose.
- The secondary market functions well because many investors participate.
- Many investors participate because companies with real value list their shares there.

The stock exchange, the subject of this entire document, is the infrastructure that makes this cycle turn.



1.8 A Word on Other Instruments

The same framework applies to other instruments:

- **Bonds** trade on bond markets (some exchange-based, others over the counter) after issuance. Investors can sell their bonds before maturity, receiving the current market price rather than waiting for repayment.
- **Futures and options** are not claims on existing assets at all, they are contracts about future transactions [12] [13]. Their markets have their own logic, but the exchange's role (centralised matching, price discovery, fairness) is the same.
- **Exchange-Traded Funds (ETFs)** are baskets of shares (or bonds, or commodities) that themselves trade as a single share. iShares, Vanguard, and SPDR products are examples. ETFs trade on exchanges exactly like individual stocks.
- **Market indices** are calculated measures of the aggregate performance of a defined basket of securities. The **S&P 500** tracks 500 large US companies (in practice slightly more than 500 share classes, because a few companies have two listed classes) and is the most closely followed equity index in the world, first

published in its current form by Standard & Poor's in 1957. The **Dow Jones Industrial Average (DJIA)**, dating to 1896, tracks 30 large US companies. The **NASDAQ Composite** tracks almost all common stocks listed on NASDAQ. Indices themselves are not directly tradeable, but **index futures** (on CME), **index options** (on Cboe), and **index ETFs** allow investors to trade the performance of a whole index with a single instrument. When a US portfolio manager says "the market is up 0.8% today," they almost always mean the S&P 500. When exchange system developers build risk calculations or position monitors, index levels are frequently the benchmark against which positions are marked.

With this foundation in place, understanding what a share is, why companies issue them, and what role the exchange plays, we can now look at the mechanics of how an exchange actually operates.

CHAPTER 2

What Is a Financial Exchange, and Why Does It Exist?

2.1 The Core Problem

Imagine you own 1,000 shares of a technology company (you understand now what that means: you own a tiny fraction of that company, acquired when you bought the shares from a previous owner on the secondary market) and you want to sell them. Somewhere out there, someone wants to buy exactly 1,000 shares of that same company at roughly the price you have in mind. The problem is finding each other.

Before modern exchanges existed, this "finding" problem was enormous. Stock trading happened in coffee houses, in the street (London's brokers congregated in the narrow lane called Exchange Alley and its coffee houses), or through networks of personal contacts. One of the first places on record was Jonathan's Coffee House, the forerunner of the London Stock Exchange, opened around 1680 by Jonathan Miles; Jonathan's became the primary gathering place for stock brokers [10]. The brokers had not come entirely voluntarily: in the 17th century they were not allowed in the Royal Exchange, reportedly because of their rude manners, so they took their business, and their noise, to the coffee houses nearby. In 1698 a broker at Jonathan's named John Castaing began publishing a regular list of prices, *The Course of the Exchange*: arguably the first market-data feed, with a latency of several days. Prices were inconsistent, you might sell at one price while, moments later, someone else sold the same shares at a very different price. There was no guarantee you were getting a fair deal, and there was no way to know what "fair" even meant.

> **Auctions by the Candle**
>
> Garraway's Coffee House was opened by Thomas Garway and famed for being one of the first places in England to sell tea (from 1657). It was rebuilt after the Great Fire of London in 1666. While Jonathan's focused heavily on shares, Garraway's specialised in commodities and was a favourite venue for auctions, including the Hudson's Bay Company's first fur sale in 1671.
>
> Garraway's was legendary for its unique bidding system: an auctioneer would light an inch of tallow candle, and the last bid placed before the flame flickered out won the goods. Candle Auction

The golden era of the informal Exchange Alley coffeehouses came to a catastrophic halt on March 25, 1748, when a massive fire broke out in Cornhill, destroying Jonathan's, Garraway's, and nearly 100 surrounding buildings. Though both shops were eventually rebuilt, the financial markets were rapidly moving toward formal, dedicated corporate buildings, leaving the casual coffeehouse model behind.

A financial exchange solves this problem by acting as a **centralised marketplace**, a single place where all buyers and sellers come together, where prices are visible to everyone, and where agreed rules govern who trades with whom at what price. The NYSE was founded in 1792 under a buttonwood tree on Wall Street [10]; NASDAQ launched in 1971 as the world's first electronic stock market [10]. Both exist to solve the same fundamental problem: matching buyers with sellers fairly and efficiently.

It is worth noting that exchanges are among the most visible matching venues, but not the only ones. **Over-the-counter (OTC) markets** (where participants negotiate directly), **Alternative Trading Systems (ATSs)**, **Electronic Communication Networks (ECNs)**, and **internalisers** (brokers who match client

orders internally against their own inventory) all also match trades. The concepts in this document apply most directly to regulated exchanges, but the same vocabulary, order book, spread, price-time priority, is used across all these venues.

2.2 The Three Promises of an Exchange

Every exchange makes three implicit promises to its participants:

1. Price discovery. At any moment, the current price of an asset reflects the aggregate opinion of all participants currently willing to trade it. You can look at the market and see what "fair value" is right now.

2. Liquidity. You can convert your asset into cash (or vice versa) quickly, without having to wait indefinitely for a counterparty to appear. The exchange provides the infrastructure that makes counterparties findable.

3. Fairness and transparency. The rules for who trades first and at what price are known in advance, applied consistently, and visible to all participants equally. There is no backroom dealing.

2.3 How Exchanges Are Regulated

Exchanges do not operate by custom alone. They are licensed and supervised by government regulators whose rules directly shape how exchange systems are designed and built.

In the United States, equity exchanges are overseen by the **Securities and Exchange Commission (SEC)**, established by the Securities Exchange Act of 1934 in the aftermath of the 1929 crash and subsequent Great Depression. The crash and its causes deserve a sentence of context here, because they explain why the SEC's mandate is what it is.

Between early 1928 and September 1929, the US stock market nearly doubled (the Dow peaked at 381.17 on 3 September 1929). Investors were buying heavily on **margin**, borrowing money to buy more stock than they could afford outright. When prices began to fall in October 1929, margin calls forced widespread selling. Selling drove prices lower, which triggered more margin calls, which drove more selling, the same feedback loop that automated portfolio insurance would recreate in 1987. The Dow Jones Industrial Average fell 89% from its 1929 peak to its trough of 41.22 in July 1932, and did not regain its 1929 peak until November 1954, a quarter of a century later. Thousands of banks failed. Millions lost their savings. The subsequent investigation found rampant stock manipulation, insider trading, misleading corporate disclosures, and conflicts of interest at every level of the market. The Securities Act of 1933 and the Securities Exchange Act of 1934 were Congress's direct response: transparency requirements, registration of securities, prohibition of fraud, and the creation of the SEC to enforce the rules. The exchange system you are building operates under the regulatory framework those 1930s laws set in motion.

Several regulations appear throughout this document and in most exchange codebases. It is worth naming them here:

- **Regulation NMS (National Market System, adopted 2005, phased in through 2007):** Its Order Protection Rule prohibits trading venues from executing an order at a price worse than the best displayed, immediately accessible quote on any other registered venue (a **trade-through**). This rule shaped the modern US landscape of well over a dozen registered equity exchanges competing for order flow, and it is the reason **smart order routing** exists: orders must reach wherever the best protected price is, not just the closest or the cheapest venue.
- **Regulation SHO (adopted 2004, in force from January 2005):** Governs short sales, including the **locate** requirement (broker-dealers must verify shares can be borrowed before accepting a short sale order) and delivery obligations.
- **Market Access Rule (Rule 15c3-5, adopted November 2010):** Requires broker-dealers providing market access to have pre-trade risk controls: maximum order sizes, credit limits, and the ability to cut off trading. It was proposed in January 2010, over concerns about "unfiltered" sponsored access in which clients' orders reached exchanges without passing through any broker checks; the May 2010 Flash Crash then added considerable urgency.

In Europe, the equivalent framework is **MiFID II (the second Markets in Financial Instruments**

Directive, together with its companion regulation MiFIR, applying from January 2018), which mandates best execution, algorithmic trading controls (including mandatory kill switch testing), trade reporting, and systematic internaliser reporting. Any exchange system intended to operate in EU markets must comply.

Understanding which regulator and which rules apply is not just a legal matter. It is an engineering specification: audit trail formats, kill switch accessibility, pre-trade check requirements, and market data publication rules are all regulatory mandates, not optional features.

The South Sea Bubble and the Bubble Act (1720)

In 1720, shares of Britain's South Sea Company rose from roughly £128 in January to nearly £1,000 by the summer, propelled by a scheme to convert government debt into company equity, before collapsing back below £200 by year-end. Parliament's response, the Bubble Act of 1720, prohibited joint-stock companies from operating without a royal charter, and modern scholarship has established the uncomfortable detail that the Act was passed in June 1720, *before* the crash, with the South Sea Company's own support: its purpose was less to protect investors than to suppress rival companies competing for the same speculative capital. The Act stayed on the books for over a century (repealed 1825) and materially shaped, many argue retarded, English corporate formation. It is the earliest large-scale demonstration of two themes that recur throughout this book: securities regulation is often written in the shadow of a specific crisis, and the entities lobbying for a rule are not always the ones the rule appears to protect. The subsequent parliamentary inquiry of 1721, which uncovered bribery of ministers with company stock, also produced one of history's first insider-dealing scandals on the record.
References: Ron Harris, "The Bubble Act: Its Passage and Its Effects on Business Organization," *Journal of Economic History* 54(3), 1994, https://www.jstor.org/stable/2123870;

2.4 Instruments: What Is Being Traded?

An exchange does not trade "things" in a physical sense. It trades **instruments**, standardised financial contracts representing ownership or obligation. The most common are:

- **Equities (stocks):** A share represents a small piece of ownership in a company. When you buy one share of Apple (ticker symbol: AAPL), you own a tiny fraction of Apple Inc. NYSE and NASDAQ are primarily equity exchanges.
- **Futures contracts:** An agreement to buy or sell something (oil, gold, a stock index) at a specified price on a specified future date. CME Group is one of the world's largest futures exchanges.
- **Options:** The right (but not the obligation) to buy or sell an instrument at a specific price before a specific date. Cboe is a major options exchange.
- **Foreign exchange (FX) pairs:** The price of one currency expressed in another, such as EUR/USD (how many US dollars one Euro buys). FX trades largely on electronic networks rather than centralised exchanges, though the principles are similar.

An equity exchange handles each **symbol** (like AAPL, MSFT, or TSLA) as a separate tradeable instrument, each with its own independent order book.

CHAPTER 3

The Language of the Market: A Short History

Before you read about participants, orders, and matching engines, it is worth pausing on something that will serve you well throughout your career working on exchange systems: **much of the language you will encounter in this codebase has historical roots that no longer match the physical reality**. Terms that sound arbitrary or old-fashioned are fossil words, the language of a world of wooden desks, brass bells, and paper ledgers that gradually evolved into the nanosecond world of today. Understanding where the words came from will make them stick, and will save you from wondering why a system full of cutting-edge software keeps referring to things like "the book," "the tape," and "the floor."

3.1 The Physical Book

Before electronic trading systems, every major exchange operated a physical trading floor, and on that floor, for every stock, there was a person responsible for maintaining order: in NYSE's terminology, this was called the **specialist**. The specialist's job was to act as a market maker for their assigned stocks, and to maintain, literally on paper, a record of every outstanding buy and sell order that had been submitted but not yet filled.

This record was kept in a physical **ledger book**. The book was divided into two columns: one for buy orders (bids) listing each buyer's offered price and quantity, and one for sell orders (asks) listing each seller's demanded price and quantity. The specialist would review the book, try to match buyers with sellers, and maintain an orderly market by quoting prices to floor brokers who came to trade.

When a broker wanted to buy shares and asked "what's the market in IBM?", the specialist would look at their book and say, for example, "fifty-five for five hundred, five hundred at fifty-five and a quarter", meaning the best available buyer was offering $55 for 500 shares, and the best available seller was asking $55.25 for 500 shares. The specialist was reading, live, from their paper book.

The physical book is gone. Every exchange in the world now maintains its order book in computer memory, with data structures designed for nanosecond access. But the **name** has survived completely intact. When developers and traders today say "the book," "working an order into the book," "resting in the book," or "taking from the book," they are using the exact same language that floor traders used when pointing at a physical ledger. The order book is one of the purest examples of terminology that crossed from physical to digital without losing a syllable.

3.2 Open Outcry and the Pit

On exchange floors like CME Group's in Chicago, trading in futures contracts was conducted through **open outcry**, a method where traders stood in a sunken circular area called a **pit** and literally shouted their bids and asks at each other, using a combination of voice and hand signals to communicate price, quantity, and direction. The noise was enormous. The system worked because the pit was small enough that everyone could hear and see everyone else.

The CME Group operated open outcry pits for decades. Some products, particularly certain agricultural and options contracts, continued in open outcry long after equity markets went fully electronic, largely because the

pit handled complex, illiquid products where human negotiation had genuine advantages. CME closed most of its futures pits in July 2015 [9]. The remaining pits were shut in March 2020 as a COVID-19 precaution, and in May 2021 CME announced that most of them would never reopen; only the Eurodollar options pit was kept [CME Group press release, 4 May 2021]. The physical pit is where terms like "floor broker" (a broker who executes trades on the physical floor), "floor trader" (a trader who trades for their own account from the floor), and "pit committee" originated.

The terms survive in documentation, regulations, and informal industry speech even though the pits themselves are mostly silent now.

3.3 The Ticker Tape

Before electronic screens, prices of completed trades were published via the **stock ticker**, a telegraph-based machine, invented by Edward Calahan in 1867 [15] and later improved by Thomas Edison, that printed a continuous stream of abbreviated stock symbols and trade prices on a narrow paper tape. The tape moved fast (hence "ticker", the machine made a ticking sound) and the strip of paper would pile up on the floor of brokerages around the country as trades printed in real time.

Reading the tape was a skill. A **tape reader** was someone who could watch the continuous stream of prices and volumes and infer what institutional buyers and sellers were doing, one of the earliest forms of technical analysis. An even earlier form of market observation appears in Joseph de la Vega's *Confusión de Confusiones* (1688) [4], the oldest known book about stock trading, written in Amsterdam about the VOC share market, which describes participants reading order flow and inferring intent from patterns of buying and selling.

The first telephones appeared on the NYSE floor in 1878, two years after Alexander Graham Bell's patent. The ticker itself kept getting faster, yet it still ran hours behind during the heavy selling of October 1929, and again, as the note below describes, in 1962. By the 1960s, electronic displays began replacing paper. Today, the "ticker" refers to the digital price feeds streaming across screens in every trading firm, brokerage, and financial news channel, and the **ticker symbol** (AAPL, MSFT, GOOG) is the abbreviated code printed on the old paper tape.

When you see terms like "tick" (the minimum price movement), "tick data" (a record of every trade), or "ticker plant" (the server infrastructure that publishes market data), you are using the language of a machine that ran on telegraph cables and printed on paper strips.

The Kennedy Slide, the Lagging Tape, and the Study That Created NASDAQ (1962–71)

On 28 May 1962 the Dow fell 5.7% in a single session, then the second-largest one-day point decline on record, in what became known as the "Kennedy Slide." Operationally, the day's defining failure was informational: trading volume so overwhelmed the ticker that the tape ran far behind actual trading, meaning investors nationwide were making decisions on prices that no longer existed. The SEC's *Special Study of Securities Markets* (1963), a multi-volume examination already underway when the break occurred, documented the episode and, more consequentially, dissected the over-the-counter market's opaque, telephone-based quotation system, recommending that OTC quotations be automated. The NASD's answer to that recommendation went live on 8 February 1971 as NASDAQ, initially not a matching engine at all, but an automated *quotation display* system, exactly what the Special Study had prescribed. The lineage is worth stating plainly: the world's first electronic stock market exists because a regulator's post-crash study concluded that stale, inaccessible price information was itself a market-structure defect. Every market-data latency requirement in Part IV is a descendant of that conclusion.
References: Kennedy Slide of 1962, Wikipedia, https://en.wikipedia.org/wiki/Kennedy_Slide_of_1962

3.4 The Language Lives in the Code

These historical terms are not just in trading rooms and textbooks. They are in the source code. A developer reading an exchange codebase for the first time will find:

- `bid_price`, `ask_price`, `spread`: the physical ledger's two columns, reduced to struct fields
- `lot_size`, `tick_size`: the standardisation introduced by the early commodity pits

- `aggressor_side`: which party crossed the spread; matters for fee calculation and regulatory reporting
- `book.add_order()`, `book.cancel_order()`, `book.sweep()`: the specialist's actions, now function calls
- `GTC`, `DAY`, `IOC`: time-in-force codes whose full names (Good-Till-Cancelled, Day, Immediate-or-Cancel) are rarely spoken, used daily in hundreds of millions of orders
- `tape_price`, `last_trade_price`: what the ticker printed, now a field in a trade record
- `long_position`, `short_position`: owning versus owing, abstracted to the sign of an integer

Every time you read a function name or a variable name in exchange software that sounds like it belongs in a different century, it does. The codebase is the physical exchange, translated.

3.5 Black Monday and the Origin of Circuit Breakers

On 19 October 1987, US stock markets fell **22.6%** in a single day, the largest single-day percentage drop in the history of the Dow Jones Industrial Average. This event, known as **Black Monday**, remains the most severe one-day market crash on record. A more detailed account of this is given in the *Risk Controls, Protecting the Market* section of Part III.

The crash was not driven by a single piece of bad news. It was amplified by automated **portfolio insurance** programmes, algorithmic selling strategies designed to protect institutional portfolios by automatically selling futures contracts as prices fell. As these programmes sold, prices fell further, triggering more programme selling, which pushed prices further down, a feedback loop that human traders could not interrupt. The lack of any coordinated mechanism to pause trading made the spiral self-reinforcing.

The Presidential Task Force on Market Mechanisms (the "Brady Commission"), reporting to President Reagan in January 1988, concluded that the absence of circuit breakers and coordinated pause mechanisms across markets had allowed the panic to become catastrophic. Its central recommendation was explicit: create automatic trading halts that could interrupt the feedback loop and give participants time to assess [Brady Commission Report, January 1988].

NYSE introduced the first market-wide circuit breakers in 1988 directly in response. The specific thresholds have been adjusted several times since (most recently after March 2020, when Level 1 was triggered four times in two weeks during the COVID-19 crash), but the mechanism traces directly to that January 1988 report.

This history matters for exchange system developers because circuit breakers are not bureaucratic decorations. They are the engineering response to a proven systemic failure mode: automated systems amplifying each other into a catastrophic spiral. Every halt threshold, every resumption auction, every "do not accept orders during HALTED state" condition in a matching engine exists because of what happened on 19 October 1987.

3.6 Settling Up: Settlement Periods and Why They Exist

The historical reason settlement took multiple days has nothing to do with technology and everything to do with physical logistics. In the era of paper stock certificates, when you sold your shares, you had to physically deliver a paper certificate to the buyer, and they had to physically deliver cash or a cheque to you. Messengers on bicycles carried these documents between brokerage firms on Wall Street. Giving everyone five business days (the original settlement period was T+5) provided time for paperwork to move across Manhattan, be checked, and be processed.

As the industry moved to dematerialisation (electronic records replacing paper certificates) and electronic funds transfer, settlement windows shrank: T+5 became T+3 in the 1990s, T+2 in 2017, and T+1 in 2024 in the US [8]. The "T+N" notation remains standard even as the N shrinks. Some markets are exploring same-day (T+0) settlement, though this requires that cash and securities be available at the exact moment of trading, a more demanding operational requirement.

3.7 The Bid, the Ask, and the Spread

The two most fundamental prices in any market are the **bid** and the **ask** (also called the **offer** in some contexts). These are ancient words in the context of markets.

Bid comes from Old English *beodan*, meaning to announce, command, or offer. To bid for something is to

announce the price you are willing to pay. A bidder at an auction makes a bid; a trader in a market makes a bid. The word has been used in commercial contexts for over a thousand years.

Ask (or offer) is the counterpart: the price at which someone is willing to sell. Asking a price for goods is as old as commerce.

The **spread** is the difference between the best bid and the best ask at any moment: if the best bid is $150.30 and the best ask is $150.35, the spread is $0.05. The spread is both a measure of market quality (tight spreads mean the market is liquid and efficient; wide spreads mean it is illiquid or uncertain) and the primary source of income for market makers, who earn the spread by continuously standing ready to buy at the bid and sell at the ask.

The phrase **"crossing the spread"** means submitting an order aggressive enough to immediately match against a resting order. An investor who submits a buy order at $150.35 (the ask) rather than waiting at $150.30 (the bid) is crossing the spread and paying for the privilege of immediate execution. This small payment, a few cents, or a fraction of a cent in liquid markets, is the cost of immediacy, and it is the foundation of the market maker's business model.

3.8 Blue Chips, Bulls, and Bears

Not all inherited terminology has to do with physical infrastructure. Some comes from adjacent worlds:

Blue chip stocks are large, well-established, financially sound companies, the most prestigious tier of the equity market. The term comes from poker: in casino chips, blue has traditionally been the highest denomination. The first recorded use in finance was by Oliver Gingold at Dow Jones in 1923, who described stocks trading at $200 or more per share as "blue chip stocks." [14]

Bull market (rising prices) and **bear market** (falling prices) have disputed origins, but the most widely cited explanation refers to how each animal attacks: a bull thrusts its horns upward, a bear swipes its paws downward. The terms appear in financial writing as early as the 18th century. Today, by widely used convention rather than by any formal rule, a market that has fallen 20% or more from a recent peak is called a bear market, and a sustained rise of 20% or more from a trough a bull market.

Going long and **going short** describe the two directions a position can face, and the practice is far older than the words. **Long** means you own (or have agreed to buy) the asset: you gain if its price rises and lose if it falls. **Short** means you have sold something you do not own (or agreed to deliver something you do not yet have): you gain if the price falls, because you can buy it back more cheaply before you must deliver, and you lose if it rises.

The *words* are younger than you might expect. The sense of "short" as "having an insufficient quantity" is recorded in English from the 1690s, and the market phrase "to sell short", meaning to sell what the seller does not at the time possess, is attested by 1852 [Online Etymology Dictionary, "short"]; nineteenth-century American usage popularised the pair. The short seller is literally *short of* the goods, in the same word family as "shortage" or "falling short". "Long" came along as its natural opposite: well supplied, holding more than enough. (You will find more romantic origin stories online, about grain warehouses and the longevity of stored goods. They are pleasant, but no dictionary supports them.)

What *is* old is the practice. Forward contracts, promises to deliver goods at a future date for a price agreed today, were common in the grain and commodity trades of the 17th and 18th centuries, and a merchant who had promised more than their warehouse held was short in every sense that matters: they would need to buy before the delivery date, and they would profit only if prices had fallen in the meantime.

The Dutch East India Company (VOC), founded in 1602, whose shares traded in Amsterdam from that same year, pioneered many instruments still in use today: transferable shares, dividend payments, and a secondary market in those shares [5] [11]. It also became the arena for what is likely the first recorded large-scale short selling operation in financial history: in 1609, a merchant named Isaac Le Maire, himself a major VOC shareholder, organised a group of traders to sell VOC shares they did not own, betting the price would fall so they could buy them back cheaply before delivery [5]. The scheme was disruptive enough that the Dutch authorities banned the practice in 1610, the earliest known attempt to regulate it [5]. The ban did not stick; short selling has been controversial, periodically banned, and always present in markets ever since.

In the code, all of this collapses into a sign. A long position is a positive quantity, a short position a negative

one, and a developer reading `position += signed_qty` in a clearing module is applying exactly the bookkeeping a 17th-century merchant would have recognised, even if the technology would be unrecognisable to them.

Historic Notes

No episode in financial history is retold more often, or more loosely, than the Dutch tulip mania of 1636–37. The legend: a whole nation ruined, fortunes traded for single bulbs, the economy wrecked, and so on largely dissolves under archival scrutiny. Contract prices for rare bulbs did rise spectacularly through late 1636 and collapse in February 1637, but the trade was concentrated among a modest circle of merchants and craftsmen dealing in *forward contracts* on bulbs still in the ground, an early lesson that a derivative on an unharvestable underlying is a bet on a price, not a purchase of a thing. Archival work has found no wave of bankruptcies and no measurable damage to the Dutch economy; the most extreme prices in the popular telling trace to moralising pamphlets written *after* the crash, not to transaction records. The episode earns its place in this book twice over: as a genuinely early forward market discovering the hard way that contract enforceability matters (many February 1637 contracts were simply never honoured, and courts largely declined to enforce them), and as a standing reminder to check the primary record before repeating a market legend.

References: Peter M. Garber, *Famous First Bubbles: The Fundamentals of Early Manias* (MIT Press, 2000), Anne Goldgar, *Tulipmania: Money, Honor, and Knowledge in the Dutch Golden Age* (University of Chicago Press, 2007).

3.9 The Operational Mechanics of Short Selling, Borrow and Locate

The historical explanation above describes the *economics* of short selling. The modern operational reality involves several additional steps that are invisible in the exchange's order book but fundamental to how clearing and settlement actually work.

You must borrow before you short. Before a participant can sell shares they do not own, they must make sure those shares can be borrowed from someone who does own them. The first step is called the **locate**: identifying a source of borrowable shares. In the US, Regulation SHO (in force since January 2005) requires broker-dealers to have reasonable grounds to believe the shares can be borrowed, so that they can be delivered on the settlement date, before accepting a short sale order. Selling short without a locate is called **naked short selling** and is generally illegal.

Where the borrow comes from. Shares available to borrow come primarily from long investors who hold shares in custody through a broker or prime broker. These holders consent (usually automatically through their account agreements) to their shares being lent out in exchange for a **lending fee**. The custodian or prime broker intermediates: they find willing lenders and lend the shares to the short seller. The short seller pays a daily lending fee (the **borrow rate**) while the position is open.

Borrow rates and hard-to-borrow stocks. Most large-cap, liquid stocks are "easy to borrow", borrow rates are near zero because many shares are available. Smaller, heavily-shorted, or thinly-traded stocks can be "hard to borrow", rates of 5%, 20%, or even higher per annum, applied daily. For a stock with a 50% annualised borrow rate, a short position held for one week costs roughly 1% just in borrowing costs, before considering any price movement. The difficulty of finding borrows can itself become a market signal: rising borrow rates indicate increasing short interest and limited available supply.

Short recall risk. The lender can recall their shares at any time (with short notice). If the lender sells their shares or instructs their custodian to recall the loan, the short seller must return the shares immediately, either by buying in the open market (a **buy-in**) or finding a new lender. In volatile markets, recalls at inopportune moments can force short sellers to cover at bad prices.

Settlement obligation. At settlement (T+1 in the US), the short seller must deliver the shares. They do not own them, they borrowed them. Their clearing position shows a negative (short) holding. The CCP ensures delivery; if the short seller fails to deliver, the failed settlement process applies.

Why this matters for exchange developers. The exchange's matching engine processes short sales exactly like any other sell order, the distinction between a short sale and a long sale is invisible at the order book level. The matching engine does not know or care whether the seller owns the shares. The borrow

and locate process happens entirely outside the exchange, in the prime brokerage and custody infrastructure. However, exchange reporting systems are required to flag short sales (in the US, short sale orders must be marked "short" in the FIX message and this appears in the audit trail), and some regulatory checks at the gateway level confirm the short sale flag is present.

3.10 Wall Street

Wall Street is named after an actual wall, a wooden palisade built in 1653 by Dutch colonists along the northern edge of their settlement (then called New Amsterdam, now Lower Manhattan) to protect against English and Native American attacks. The wall is long gone; the street that replaced it became the financial centre of America, and now "Wall Street" is a metonym for the entire US financial industry, regardless of where the actual firms are physically located.

3.11 Why This Matters for You

When you encounter a term in the codebase that seems oddly concrete for a piece of software, "the book," "the tape," "the spread," "the floor price," "tick by tick", the reason it sounds physical is that it *was* physical. These words have been used continuously, with the same meanings, through every technological revolution the industry has undergone, because the underlying concepts remained constant even as the implementation changed completely.

This is also why you will find financial terminology resistant to renaming even when better alternatives exist. Saying "priority queue" instead of "the book" would be technically precise but professionally unintelligible. Finance is a conservative industry with deep institutional memory, and the vocabulary is part of that memory. Learning the words, and where they came from, is learning the culture.

CHAPTER 4

The Participants

Before diving into mechanics, it helps to know who is actually in the room.

4.1 Traders and Investors

The broadest category of participant is anyone who buys or sells for themselves, whether they are profit-seeking or managing risk.

Retail investors are individuals trading their own money, typically through brokerage apps (Robinhood, Fidelity, Schwab, eToro). Retail orders tend to be small (a few hundred shares at most), arrive randomly throughout the day, and, critically, are considered **uninformed flow** by market makers, meaning they are statistically unlikely to be based on superior information about the company's near-term prospects. Retail flow is therefore profitable to serve: the spread can be captured with low adverse selection risk.

Institutional investors are organisations managing money on behalf of others: pension funds, mutual funds, hedge funds, insurance companies, sovereign wealth funds, endowments. They trade in sizes that can move markets, a pension fund rebalancing its portfolio may need to buy or sell millions of shares over days or weeks without moving the price against itself. Their orders are typically routed through execution desks that use VWAP algorithms, dark pools, and smart order routing to minimise market impact. The largest institutional investors (BlackRock manages over $10 trillion in assets [1]) have more market influence than many sovereign nations.

The distinction between retail and institutional matters for exchange designers because the two populations have different latency tolerances, different order sizes, different information sets, and different legal frameworks governing their trading. Payment for Order Flow (PFOF) exists because retail flow is genuinely more profitable to service than institutional flow, and this shapes the routing decisions of retail brokers.

In exchange terminology, when a participant submits an aggressive order that immediately executes against a resting order in the book, they are called a **taker**, they are "taking" liquidity that was already available. The participant whose resting order was filled is the **maker** (they "made" liquidity available).

4.2 High-Frequency Trading (HFT) and Proprietary Trading Firms

A distinct and important participant type that does not fit neatly into the retail/institutional or maker/taker classification is the **high-frequency trading (HFT) firm** and broader class of **proprietary trading firms** (often called "prop shops").

These firms trade entirely for their own account, with their own capital, using automated strategies. They do not manage client money and do not act as brokers. Well-known firms include Citadel Securities, Virtu Financial, Jane Street, Jump Trading, and IMC. Some (like Citadel Securities and Virtu) are primarily market makers; others run arbitrage and statistical arbitrage strategies.

HFT firms are estimated to account for approximately 50% of equity trading volume on US exchanges [1], and a significant portion of derivatives volume. They make markets extremely tight (narrow spreads) in liquid

products because competition between HFT market makers is intense. They also create controversy: critics argue that latency arbitrage gives them an unfair structural advantage over slower participants; defenders argue that their market making activity lowers costs for everyone.

For exchange developers, HFT firms are the most technically demanding participants. Their latency requirements drive the design of co-location services, the nanosecond timestamping standards, and the deterministic processing guarantees that define high-performance matching engine architecture. When an exchange system must process millions of messages per second with microsecond response times, it is largely because HFT participants require it.

4.3 Market Makers

This is a concept worth understanding deeply, because it is central to how exchanges actually work in practice, and because the exchange system you are building contains a significant amount of code dedicated specifically to managing market makers.

A **market maker** is a professional participant who continuously quotes both a buy price and a sell price for an instrument. They are simultaneously willing to buy from anyone who wants to sell, and to sell to anyone who wants to buy. In exchange for taking on this obligation, they earn the **spread**, the small gap between the price they will buy at and the price they will sell at. Market makers are the reason you can usually buy or sell a stock immediately without waiting for a human counterparty to appear. Their standing orders are already in the book, waiting.

NYSE has what it calls **Designated Market Makers (DMMs)**, specific firms assigned to each stock with obligations to maintain fair and orderly markets. Nasdaq calls them **Market Makers**. Eurex, the European derivatives exchange, runs a formal **Market Making Programme** with contractual quoting obligations. When a market maker's resting order is later filled by someone else's incoming order, the market maker is called a **maker** (they "made" liquidity available). The person whose order triggered the fill is the **taker**. Exchanges frequently give makers a fee rebate and charge takers a fee, to incentivise the provision of liquidity.

> **Key idea:** Market makers earn the spread by continuously providing two-sided quotes, a standing bid and ask, making it possible for others to trade immediately at any time. They are not passive: their position changes with every fill, and they must manage inventory and information risk in real time. The *Market Makers* section of Part II examines the full operational detail: formal obligations, what happens when a quote is hit, protection mechanisms, and the software implications of supporting them.

4.4 Brokers

Broker itself is an old word. It traces back to Middle English *brocour* and Anglo-Norman *abrocour*, meaning a middleman or small trader. A popular, though not certain, explanation links it to the wine trade: a person who "broaches" (opens) a cask and sells the wine retail, an intermediary between producer and consumer. By the late medieval period it had generalised to any trade intermediary, and it has carried that meaning into finance.

A broker does not trade for their own account. They act as an intermediary: they receive orders from clients and submit them to the exchange on the client's behalf. Retail brokerages (Fidelity, Schwab, eToro) aggregate small orders from millions of individuals. Institutional brokers (Goldman Sachs, Morgan Stanley, JPMorgan) execute large block orders for institutional clients with minimum market impact.

Prime brokers are a specific tier of broker providing a package of services to sophisticated clients, primarily hedge funds: securities lending (enabling short selling), leveraged financing, consolidated clearing and custody across multiple brokers, and sometimes execution services. Without a prime broker relationship, a hedge fund could not efficiently short sell or use leverage. The major prime brokers are divisions of the large investment banks.

4.5 The Exchange Itself

The exchange is not a passive infrastructure provider. It is a regulated entity that enforces rules, monitors for manipulation, reports trades to regulators, and ensures the market functions fairly. In many jurisdictions, exchanges are themselves public companies listed on exchanges (NYSE's parent company, ICE, is listed on NYSE; NASDAQ lists on Nasdaq).

A significant historical shift: exchanges used to be **member-owned mutuals**, non-profit organisations run for the benefit of their broker-dealer members. Over the past 30 years, most major exchanges have **demutualised**, converting to for-profit public companies. NYSE demutualised and became a public company in 2006; the London Stock Exchange demutualised in 2000 and listed its own shares in 2001. This shift changed the incentive structure of exchanges: they now compete for order flow and listing fees, and their technology investment decisions are driven partly by shareholder returns.

4.6 Regulators

Regulators are not participants in the traditional sense, they do not submit orders, but they are the most consequential stakeholders in exchange system design. Every audit trail format, kill switch requirement, pre-trade check, and trade report exists to satisfy a regulatory obligation.

In the US, the **SEC** oversees equity exchanges and broker-dealers. The **CFTC** oversees futures and derivatives exchanges. **FINRA** (Financial Industry Regulatory Authority) is a self-regulatory organisation that oversees broker-dealers. Exchanges themselves are also self-regulatory organisations (SROs): they have obligations to monitor their own markets and report suspicious activity.

Internationally: the **FCA** (Financial Conduct Authority) in the UK, **ESMA** (European Securities and Markets Authority) and national regulators under MiFID II in the EU, the **FSA** in Japan, the **SFC** in Hong Kong, and ASIC in Australia.

For exchange developers, the practical implication is that regulatory requirements are non-negotiable features. A matching engine that produces a legally insufficient audit trail is not a working matching engine, regardless of its throughput. Understanding which regulator and which ruleset governs a given exchange is part of the technical specification.

> **Note, quotes vs orders:** Throughout this document, the terms "order" and "quote" are sometimes used to describe resting instructions in the book. Operationally they are different: a **quote** is a two-sided bid/ask pair submitted by a market maker (a single instruction generating two linked legs), while an **order** is a one-sided instruction submitted by any participant. A quote may internally generate one or two order records with linked identifiers; quote IDs and order IDs may differ. The *Market Makers* section of Part II covers this distinction in detail.

CHAPTER 5

A Brief Tour of Real-World Exchanges

To ground these concepts in reality, here is a brief overview of the exchanges most relevant to exchange system developers.

5.1 NYSE (New York Stock Exchange)

Founded in 1792, NYSE is the world's largest equity exchange by market capitalisation of listed companies. Its founding is traced to the **Buttonwood Agreement** of 17 May 1792, when 24 stockbrokers signed a document, traditionally said to have been under a buttonwood (sycamore) tree on Wall Street, agreeing to give each other preference in their dealings and never to charge less than a fixed minimum commission [10]. This agreement established the principle of a closed, rule-governed professional market, the model that all regulated exchanges follow today.

NYSE is a **hybrid market**: it combines electronic order matching with **Designated Market Makers (DMMs)** who have responsibilities to maintain fair and orderly markets and can intervene manually in certain situations. NYSE uses price-time priority and runs opening and closing auctions. Its closing auction is among the most important pricing events in global finance, determining the official closing prices that benchmark trillions of dollars of fund performance.

Despite being the iconic "stock exchange," NYSE handles only a fraction of total US equity volume. Due to fragmentation under Reg NMS, all of the NYSE group's exchanges together typically account for only around a fifth of US equity volume, and the flagship NYSE market alone for considerably less [1]; the rest goes to Nasdaq, Cboe, other exchanges, and the dozens of off-exchange venues (dark pools and broker internalisers) that in recent years have executed close to half of all US equity volume. This is not a sign of weakness, it reflects the fragmented, competitive nature of modern US equity markets.

The Panic of 1792 and the Buttonwood Agreement

The Buttonwood Agreement of 17 May 1792 did not appear out of calm deliberation. Weeks earlier, New York had suffered the young republic's first financial panic: William Duer, a former Treasury official, had borrowed heavily to corner Bank of New York shares and government debt, and his failure in March 1792 set off a cascade of defaults. Alexander Hamilton's Treasury responded with open-market purchases of government securities and by encouraging banks to keep lending against good collateral, actions economic historians have described as a remarkably modern lender-of-last-resort operation, some eight decades before Walter Bagehot set out the doctrine in *Lombard Street* (1873). The 24 brokers who signed the Buttonwood Agreement that May were, in part, organising to restore confidence after the chaos: giving each other preference, at a fixed minimum commission of one-quarter percent, under known rules. The agreement is a single sentence long, and it is the founding text of American self-regulated exchange trading, written as a direct response to the market's first blow-up.
References: The Buttonwood Agreement, https://en.wikipedia.org/wiki/Buttonwood_Agreement

5.2 NASDAQ

NASDAQ launched in 1971 as the world's first electronic stock market, initially an automated quotation system for over-the-counter stocks rather than an exchange; it became a registered national securities exchange in 2006. It is home to many of the world's largest technology companies (Apple, Microsoft, Amazon, Alphabet). NASDAQ is a pure electronic market: no trading floor and no DMMs in the NYSE sense. It pioneered the technology approach to exchange operation and drove down transaction costs dramatically.

5.3 CME Group (Chicago Mercantile Exchange)

CME Group is the world's largest futures exchange group by most measures, operating CME, CBOT (Chicago Board of Trade), NYMEX, and COMEX. (By total number of derivatives contracts traded, India's National Stock Exchange has ranked first in recent years, driven by enormous volumes of very small index options.) Futures contracts on everything from interest rates to agricultural commodities to weather indices trade here. CME uses the Globex electronic trading platform, which processes millions of orders per day. CME uses both price-time priority and pro-rata allocation depending on the product.

5.4 Eurex

Part of Deutsche Börse Group, Eurex is Europe's largest derivatives exchange, headquartered in Frankfurt. Eurex is known for its sophisticated market making programmes, and its Market Maker Protection (MMP) functionality is a widely studied example of the protection mechanisms described in Part II. Deutsche Börse's T7 trading system is also used by several other exchanges.

5.5 LSE (London Stock Exchange)

The LSE is one of Europe's oldest exchanges, dating to the 17th century coffee houses. It trades equities, bonds, and ETFs. The LSE uses the SETS (Stock Exchange Electronic Trading System) for liquid equities and runs opening and closing auctions. The LSE's Millennium Exchange technology platform has also been licensed to a number of other exchanges.

Historic Note: The Big Bang, 27 October 1986

The modern LSE is largely the product of a single day of deregulation known as the **Big Bang**. Until 1986, the LSE operated under a cartel-like structure inherited almost unchanged from its coffee-house origins: brokerage commissions were fixed by rule rather than set by competition, and firms were legally separated into **brokers** (who dealt with clients) and **jobbers** (who traded as principals on the floor), with outside and foreign ownership of member firms tightly restricted. On 27 October 1986, all of this changed at once: fixed commissions were abolished, the broker/jobber distinction was scrapped, non-member and foreign ownership was permitted, and open-outcry floor trading was replaced almost overnight by the screen-based **SEAQ** electronic quotation system. The changes were bundled together deliberately, as a negotiated settlement of a long-running restrictive-practices case brought by the UK government against the exchange, and the government wanted them delivered as a single event rather than a gradual transition. The effect was to compress a decade of gradual American-style deregulation into one day, and it is the direct reason the LSE moved from a floor-based, fixed-commission market to the electronic, competitive one described in this document.

Big Bang has an almost exact American predecessor: on **1 May 1975** ("**May Day**"), the SEC abolished fixed brokerage commissions on the NYSE, ending nearly two centuries of fixed-rate trading that dated back to the original 1792 Buttonwood Agreement described earlier in this chapter. Commission rates had been fixed by NYSE rule for so long that the change was existential for many old-line brokerages; it also created the discount-brokerage industry (Charles Schwab's firm began offering discounted commissions that same year) and set in motion the competitive, cost-conscious order-routing dynamics, including, decades later, payment for order flow, that the *Smart Order Routing* section of Part IV describes in detail. May Day and Big Bang are worth holding in mind together: eleven years apart, one American and one British, both replacing a fixed-price professional cartel with open price competition, and both direct ancestors of the fee-driven, technology-mediated market structure this book describes throughout.

Reference: Big Bang 20 years on, CENTRE FOR POLICY STUDIES, https://web.archive.org/web/20211015091533/https://www.cps.org.uk/files/reports/original/111028101637-20061019EconomyBigBang20YearsOn.pdf

5.6 Euronext

Euronext is continental Europe's largest exchange group, operating markets in Amsterdam, Brussels, Paris, Lisbon, Dublin, Oslo, and Milan. Originally formed in 2000 by the merger of the Paris, Amsterdam, and Brussels exchanges, it expanded significantly through subsequent acquisitions including the Milan Stock Exchange (Borsa Italiana) in 2021. Euronext uses the **Optiq** trading platform and operates under MiFID II. Its Amsterdam exchange is historically notable as the successor to what is widely regarded as the world's first stock exchange, where VOC shares traded from 1602.

5.7 Nasdaq Stockholm (Stockholmsbörsen, STO)

Nasdaq Stockholm is Sweden's primary regulated securities exchange and one of the core venues in the Nordic region. The original Stockholm Stock Exchange dates to 1863, and the modern market became part of the Nasdaq group through Nasdaq's acquisition of OMX in 2008. Today, Nasdaq Stockholm operates as part of the wider Nasdaq Nordic market structure alongside Copenhagen, Helsinki, and Icelandic venues.

For exchange developers, Nasdaq Stockholm is a useful real-world reference because it combines deep local equity liquidity with a highly standardised pan-Nordic technology model. The market is fully electronic, supports auction phases (including opening and closing auctions), and runs under the same MiFID II transparency and best-execution regime as other EU venues.

The venue's best-known benchmark is the **OMXS30** index, which tracks the 30 most traded shares on Nasdaq Stockholm. The exchange is the home listing venue for many major Swedish and Nordic companies, including names such as Ericsson, Volvo, Atlas Copco, and Investor AB, making it central to Nordic equity price discovery.

From an infrastructure perspective, Nasdaq Stockholm aligns with broader Nasdaq market technology standards (including INET-based matching architecture for cash equities) and interoperates with regional post-trade infrastructure such as Euroclear Sweden for securities settlement. In practical terms, this makes it a strong example of how a national exchange can preserve local market identity while operating inside a larger cross-border technology and regulatory framework.

5.8 IEX (Investors Exchange)

IEX launched as a dark pool in 2013 and became a registered national securities exchange in 2016. It is the exchange that popularised the **speed bump**: a deliberate 350-microsecond delay applied to incoming orders, designed to level the playing field between HFT latency arbitrage strategies and slower institutional investors. IEX was the subject of Michael Lewis's 2014 book *Flash Boys*, which brought widespread public attention to HFT and exchange structure debates.

The speed bump attracted significant institutional support from large asset managers who believed it reduced predatory latency arbitrage. However, IEX has consistently captured a relatively small share of US equity volume (typically 2–3%) [1], suggesting that the speed bump's appeal did not translate into dominant market share. Whether this reflects genuine limitations of the model or simply the difficulty of displacing entrenched incumbent exchanges remains debated in market structure circles. IEX remains disproportionately influential in regulatory discussions given its size, having prompted rule-making discussions at the SEC around speed bumps and exchange access fees.

5.9 Cboe (Chicago Board Options Exchange)

Cboe Global Markets is the largest US options exchange group, operating Cboe Options, C2, BZX, BYX, EDGX, and EDGA among others. Cboe invented the listed options market in 1973. It calculates the VIX (Volatility Index, the "fear gauge" of the market) from options prices.

5.10 JPX (Japan Exchange Group)

JPX was formed in 2013 by merging the Tokyo Stock Exchange (TSE) and Osaka Securities Exchange. It is consistently one of the world's largest exchanges by market capitalisation of listed companies, generally ranked just behind NYSE and NASDAQ and close to Shanghai, though the precise ordering shifts from year to year and depends on whether Shanghai and Shenzhen are counted as one market or two, so any "top three" claim should be checked against a dated source (e.g., World Federation of Exchanges statistics) rather than treated as fixed. JPX operates on an all-electronic platform called arrowhead. Japanese markets have their own session structure, tick size rules, and circuit breaker conventions; the daily price limit system (where trading in a stock is suspended if it moves more than a set amount from the previous close) differs from the US LULD approach.

5.11 HKEX (Hong Kong Exchanges and Clearing)

HKEX is the primary exchange for Hong Kong-listed equities and also provides the main electronic gateway for mainland China stocks through the Shanghai-Hong Kong Stock Connect and Shenzhen-Hong Kong Stock Connect programmes. Stock Connect allows international investors to trade China A-shares (mainland China stocks) and allows mainland investors to trade Hong Kong-listed stocks through a northbound/southbound quota system, a unique regulatory and technical arrangement in which orders are routed across the border to the other market's matching engine, subject to real-time quota control.

5.12 SGX (Singapore Exchange)

SGX is Southeast Asia's largest exchange, trading equities, derivatives, and fixed income. It is notable as a hub for Asian futures contracts, Nikkei 225 futures, MSCI Asia index futures, and iron ore contracts all trade on SGX. SGX acquired Scientific Beta (factor indices) and has invested heavily in data analytics services alongside its exchange operations.

5.13 ASX (Australian Securities Exchange)

ASX serves the Australian equity and derivatives markets. It became notable in the technology community for its attempt to replace its CHESS (Clearing House Electronic Subregister System) settlement platform with a blockchain-based system, a project that was cancelled in November 2022 after years of development, with ASX writing off roughly A$250 million. The cancellation is a cautionary tale for exchange technologists about the risks of replacing proven settlement infrastructure with unproven technology.

CHAPTER 6

Listing and Delisting Mechanics

The *Before the Exchange* section described the IPO from the company's side: underwriters, roadshows, pricing. This section first looks more closely at how an IPO actually gets its price, then closes the loop from the exchange's side. Going public is not just a financial event, it is an application to a specific exchange, governed by that exchange's own rulebook, and staying listed is an ongoing obligation, not a one-time achievement.

6.1 Why Exchanges Compete for Listings

A listing is valuable to an exchange for reasons beyond the one-off listing fee. A listed company generates ongoing order flow (every share ever traded on that exchange contributes to trading revenue), market data revenue (see *Market Data Economics* in Part IV), and prestige that attracts further listings. This is why exchanges actively court companies before an IPO, and why the choice between, say, NYSE and NASDAQ for a marquee technology company is itself a competitive sales process, not a formality.

6.2 How an IPO Gets Its Price

Every IPO has to answer one question before a single share can trade: *what is this company worth, and therefore what should one share cost?* Ask five people how that number is found and you will get five answers. An investment banker will describe a disciplined process of financial models, peer comparisons and investor meetings. A venture capitalist will talk about the "story" and the size of the opportunity. A finance professor will talk about discounted cash flows. A cynical trader will say the price is whatever the banks think they can sell the shares for on the day. All of them are partly right. IPO pricing is a structured process wrapped around an irreducible core of judgement, market mood and, at times, something close to black magic.

The valuation scholar Aswath Damodaran draws a distinction that helps make sense of this. **Valuing** a company means estimating what its business is worth from its fundamentals, because in the end "it's cash in, cash out. You can't get away from that." **Pricing** a company means looking at "what other people are paying" for similar assets and "trusting the crowd on average to get it right" [Damodaran, interviewed by The Acquirer's Multiple, 2024]. An IPO is fundamentally a *pricing* exercise dressed in the language of *valuation*: the models set a plausible range, but the final number is the price at which enough real investors, on a particular week, are willing to buy.

Why getting the number "right" matters so much

The price has to thread a needle:

- **Too high, and the deal fails.** Investors refuse to buy, the offering has to be cut or pulled, or the shares sink below the offer price soon after trading starts (Wall Street calls this "breaking issue"). The damage is lasting: early buyers lose money, the company's reputation suffers, and raising more capital later becomes harder. Facebook raised its price range from $28–$35 to $34–$38, priced at the top, $38, raised $16.08 billion at a valuation of $104.2 billion in May 2012 [Forbes, 17 May 2012], and then fell below $38 on its second trading day. It spent more than a year below its offer price.

- **Too low, and the company "leaves money on the table".** If the shares are priced at $20 and trade at $40 on day one, the company sold part of itself for half of what the market was demonstrably willing to pay. The difference went to the lucky first buyers, not to the company. Snowflake raised its range twice (the top rose from $85 to $110), priced its September 2020 IPO at $120, above even the raised range, and sold 28 million shares for $3.36 billion [CNBC, 15 September 2020]. The stock then more than doubled on its first day, closing at about $254. On those 28 million shares, the gap between the offer price and the first close was roughly 28 million × $134 **$3.75 billion**: more than the company itself raised.

Most IPOs are deliberately priced a little low. Across US IPOs from 1980 to 2025 the average first-day return was about **19%**, and at the height of the dot-com bubble in 1999–2000 it averaged about **65%**; in total, some $250 billion has been "left on the table" over that period [Jay Ritter, *IPO Statistics*, University of Florida] (see Initial Public Offerings: Updated Statistics). A modest first-day rise is seen as healthy: it rewards the investors who committed early, creates good publicity, and makes the next offering easier. A huge first-day jump, on the other hand, usually means the price was wrong.

The paperwork: the S-1 in the US, the prospectus in the EU

The S-1. In the United States, a company offering shares to the public must register them with the SEC under the Securities Act of 1933. For a US company the registration statement is **Form S-1**; a foreign company typically files the equivalent **Form F-1**. The S-1 contains the **prospectus**, the document every investor is given, plus additional information for the SEC. It is long, often several hundred pages, and describes the business, its risks (the "risk factors" section alone can run to dozens of pages), audited financial statements, management and pay, who owns what before and after the offering, and the terms of the deal.

The process runs roughly as follows. Most companies first submit a draft **confidentially**, so that the SEC's staff can comment before anything becomes public; the SEC's staff review the filing and send comment letters, and the company answers and amends until the comments are resolved. The public filing then goes out, followed by a *preliminary* prospectus that includes the proposed price range, traditionally nicknamed the **red herring** after the red warning text on its cover saying that the document is not yet final. Once the SEC declares the registration statement **effective**, the shares can be sold, and the final price appears in the final prospectus.

Two parts of the S-1 deserve special attention, because they shape how the market will see the company:

- **Classification.** The cover of Form S-1 asks for the company's **Primary Standard Industrial Classification (SIC) code**. It sounds bureaucratic, but classification decides which SEC review office examines the filing, which peer companies analysts will compare it with, and, eventually, in which sector index providers place it. It is therefore also part of the *story*. When SpaceX filed for its 2026 IPO, it was widely reported to have chosen SIC code 7370, computer programming and data processing, rather than an aerospace code, placing itself alongside software and AI companies rather than rocket makers. Separately, the US JOBS Act of 2012 created the **emerging growth company** category for smaller issuers (defined by annual revenue below roughly $1.2 billion), which may file with reduced disclosure. How a company is classified affects both its obligations and its valuation.
- **Use of proceeds.** SEC rules (Item 504 of Regulation S-K) require the prospectus to state what the company intends to do with the money it raises. The answer matters to investors in two ways. First, an IPO can sell **primary** shares, newly issued by the company, whose proceeds go to the company, and **secondary** shares, sold by existing shareholders such as founders and venture capital funds, whose proceeds go to *them*. A deal that is mostly secondary is an exit for insiders, not fresh capital for the business, and investors read it accordingly. Second, a specific plan ("build three factories", "repay this loan") is easier to judge than the vague and very common "general corporate purposes".

The EU prospectus. In the European Union the equivalent document is the **prospectus** required by the Prospectus Regulation (Regulation (EU) 2017/1129). It is approved by the *national competent authority* of the company's home member state (BaFin in Germany, the AFM in the Netherlands, Finansinspektionen in Sweden, and so on), and once approved it can be **passported**: used to offer the shares across the whole EU without a second approval. Its content is standardised by EU rules and covers the same ground as an S-1, including a required section on the **reasons for the offer and the use of proceeds**. The regime has just been revised by the EU Listing Act (Regulation (EU) 2024/2809), whose amendments to the Prospectus Regulation apply from 5 June 2026, with the aim of making prospectuses shorter, more standardised and

cheaper to produce. The United Kingdom, outside the EU since 2020, runs its own separate prospectus regime.

The valuation toolbox

Bankers and investors use two families of tools, and every serious IPO uses both.

Comparable companies ("comps"). Find listed companies that look similar, see what the market pays for them relative to some measure of their business, and apply the same multiple. Common multiples are **price-to-earnings (P/E)** (share price divided by profit per share), **EV/EBITDA** (enterprise value, meaning the value of the whole business including its debt, divided by earnings before interest, tax, depreciation and amortisation) and, for companies without profits, **EV/Sales**. If similar companies trade at 20 times earnings and our company earns $100 million, a comps-based value is about $2 billion. This is *pricing* in Damodaran's sense: it inherits whatever optimism or pessimism is already in the comparable stocks.

Discounted cash flow (DCF). This is *valuing* in the intrinsic sense. A company is worth the cash it will generate for its owners in the future, adjusted for the fact that money later is worth less than money now. Two ideas carry the whole method:

- **Discounting.** $100 received a year from now is worth less than $100 today, because today's $100 could be invested in the meantime and because the future is uncertain. With a **discount rate** of 9%, $100 in one year is worth 100 / 1.09 $91.74 today, and $100 in five years is worth 100 / 1.09 $64.99. The discount rate reflects the return investors demand for the risk they take; riskier businesses get higher rates.
- **Terminal value.** Nobody can forecast cash flows forever, so analysts forecast a few years in detail and then assume steady growth from then on. A cash flow C growing at rate g forever, discounted at rate r, is worth C / $(r - g)$ (the "Gordon growth" formula).

A worked example. A company's free cash flow (the cash left after running and investing in the business) is $100 million this year. Analysts expect it to grow 10% a year for five years, then 3% a year forever, and they use a 9% discount rate:

Year	Free cash flow $(m)\|Discount factor 1/1.09^t\|Present value$(m)		
1	110.0	0.917	100.9
2	121.0	0.842	101.8
3	133.1	0.772	102.8
4	146.4	0.708	103.7
5	161.1	0.650	104.7
		Sum of years 1–5	**513.9**

The terminal value at the end of year 5 is 161.1 × 1.03 / (0.09 − 0.03) $2,765 million, worth 2,765 / 1.09 $1,797 million today. The business is therefore worth about 513.9 + 1,797 **$2.31 billion**.

Two lessons hide in that arithmetic, and both matter enormously for IPOs:

1. **Most of the value is in the distant future.** About 78% of the $2.31 billion comes from the terminal value, from cash flows *after* year five, which nobody can forecast with any confidence.
2. **Small changes in assumptions cause big changes in value.** Use an 8% discount rate instead of 9% and the value rises to about $2.79 billion (+21%); use 10% and it falls to about $1.97 billion (−15%). A one-point disagreement about risk moves the answer by hundreds of millions of dollars.

From company value to share price. Suppose the valuation work (DCF, comps, and conversations with investors) lands at an equity value of about $2.3 billion for a company with 100 million shares outstanding before the IPO: about $23 per share. The underwriters will typically propose a range somewhat below that, say $19–$21, building in the deliberate **IPO discount** that rewards early buyers for taking a chance on an untested stock. If the company then sells 20 million *new* shares at $20, it raises $400 million, and afterwards there are 120 million shares outstanding.

When the toolbox breaks: valuing hype

The DCF method works best for businesses with positive, reasonably predictable cash flows. It struggles badly with the companies that attract the most excitement: young businesses that burn cash today and promise enormous cash flows later. For them, the near-term cash flows are *negative*, so essentially all of the value sits in a terminal value many years out, built on assumptions about growth, margins and competition that are close to guesses. Change the guesses slightly and the value can move by a factor of two or three.

Analysts therefore often run the method backwards. A **reverse DCF** asks: *what would have to be true for today's price to make sense?* Take SpaceX, which priced its June 2026 IPO at $135 per share, a valuation of about $1.77 trillion, against 2025 revenue of $18.7 billion and an operating loss of $2.6 billion [Fortune, 20 May 2026]. That is roughly 95 times last year's revenue. A deliberately simple reverse DCF: an investor who wants a 10% annual return needs the company to be worth about $1.77 trillion $\times$ 1.1^{1} $4.6 trillion in ten years. At a mature price-to-earnings ratio of 25, that requires annual profits of about $184 billion; at a healthy 20% profit margin, that requires annual revenue of about $920 billion. Growing from $18.7 billion to $920 billion in ten years means growing about **48% a year, every year, for a decade**. Perhaps that will happen; the point is that the price is a statement of belief about the far future, not a conclusion derived from present-day numbers. Independent valuations of the same company at the time ranged from well under a trillion dollars to around $1.3 trillion, which shows how much room the method leaves.

The TAM argument. When the cash flows cannot carry the valuation, the story often shifts to the size of the opportunity. The **total addressable market (TAM)** is the total revenue available if a company captured *all* of the demand for what it sells. (Analysts often narrow it further to the *serviceable* market the company can realistically reach, and to the share it can realistically obtain.) A huge TAM makes a high valuation look modest: capture "just" a few percent of a multi-trillion-dollar market and today's price seems cheap. Recent prospectuses have made remarkable TAM claims:

- **Uber (2019)** described a total addressable market of about **$12 trillion** across personal mobility, food delivery and freight [Forbes, 22 April 2019].
- **WeWork (2019)** claimed a **$3.0 trillion** market opportunity in 280 target cities, noting that it had realised "approximately 0.2%" of it [WeWork S-1, August 2019], while its 2018 revenue was about $1.8 billion against a net loss of about $1.9 billion.
- **SpaceX (2026)** claimed a TAM of **$28.5 trillion**, of which $26.5 trillion, about 93%, was attributed to artificial intelligence rather than to rockets or satellite internet [Fortune, 20 May 2026].

TAM is a useful sanity check on whether a business *could* become large. It is a poor guide to whether it *will*, because it says nothing about competitors, pricing power, costs or execution. Several spectacular failures had impressive TAMs. WeWork was valued at **$47 billion** in a private funding round in January 2019; it filed its S-1 on 14 August 2019; within weeks the valuation being discussed fell to about $10 billion; the IPO was withdrawn on 30 September 2019; the company later listed through a SPAC merger in October 2021 at about $9 billion and filed for bankruptcy on 6 November 2023 [Forbes, 7 November 2023].

History offers plenty of company for WeWork. **Pets.com** went public in February 2000 at $11 per share, raising $82.5 million, and announced its liquidation on 7 November 2000 with its shares at $0.19, having become famous mainly for its sock-puppet mascot. **Rivian** raised its range from $57–$62 to $72–$74 and then priced its November 2021 IPO at $78, valuing the electric-truck maker at about $66.5 billion, although its prospectus showed that it expected quarterly revenue of between zero and $1 million and it had not yet delivered vehicles to customers [CNBC, 9 November 2021]. On its first trading day its market value passed Ford's; a few years later its shares traded at a small fraction of the IPO price. The pattern is the same each time: the valuation rested on a story about the future, and the future turned out different.

None of this means hyped valuations are always wrong. Amazon went public in May 1997 at $18 per share as an unprofitable online bookseller, and Google's 2004 IPO valued it at about $23 billion; both look like bargains in hindsight. The honest conclusion is that for high-growth companies, the IPO price is a bet, and the process described next is how the market places it.

Book-building: discovering the price

A conventional US IPO establishes its price through **book-building**, a process run by the lead underwriters (the "bookrunners"):

1. **Setting a range.** Using the valuation work above and early informal conversations with investors ("testing the waters"), the company and its underwriters publish a **price range** in the preliminary prospectus, for example $19–$21 per share.
2. **The roadshow.** Management and bankers spend one to two weeks presenting to institutional investors (mutual funds, pension funds, hedge funds), historically in person across several cities, today largely by video.
3. **Building the book.** Investors submit **indications of interest**: how many shares they would buy, and often at what maximum price. These are not binding orders. The bookrunners record them in "the book" and watch how much demand there is at each price and from which kinds of investors. A book "covered ten times" has indications for ten times the shares on offer.
4. **Revising the range.** If demand is strong, the range is raised (Facebook, Snowflake and Rivian all raised theirs); if it is weak, the range is lowered or the deal is made smaller. CoreWeave, an AI cloud company, marketed its shares at **$47–$55** in March 2025 but priced at **$40**, below the range, and cut the deal to 37.5 million shares, raising $1.5 billion [CoreWeave press release, 27 March 2025; Reuters]. Within days of its debut the stock had risen well above the offer price, a reminder that a weak book says as much about the market's mood that week as about the company.
5. **Pricing.** The final price is set on the evening before trading begins, after the SEC declares the registration effective. The underwriters then **allocate** shares. Allocation is discretionary, not pro-rata: underwriters favour investors they expect to hold for the long term over those they expect to "flip" the shares on day one.
6. **The first trade.** The next morning, the stock opens on the exchange through a special opening auction (on NASDAQ the **IPO Cross**), using exactly the equilibrium-price mechanics described in the *Opening and Closing Auction* chapter of Part II. The IPO price is what the company received; the opening auction price is the market's first verdict.
7. **The greenshoe.** Underwriters usually have an **over-allotment option**, known as the **greenshoe** after the 1960s Green Shoe Manufacturing Company deal that first used it, to sell up to 15% more shares than planned. They can use it to support the price if it falls in early trading ("stabilisation") or simply sell the extra shares if demand is strong.

For this work the underwriters earn a fee, the **gross spread**, deducted from the proceeds. On moderate-sized US IPOs it has remained at about **7%** for decades [Ritter, *IPO Statistics*]; mega-deals negotiate far less (SpaceX's banks reportedly took under 1%).

Book-building is a custom, not a law

Nothing in US or EU law requires a company to use book-building. The securities laws regulate *disclosure* (what the prospectus must say and when shares may be sold), not the *method* by which the price is found. Book-building dominates because underwriters prefer it and issuers value the guarantee and the investor relationships that come with it. The alternatives are real:

- **Auctions.** Google's August 2004 IPO used a modified **Dutch auction**, open to large and small investors alike, in which bidders named a price and quantity and a single clearing price was set from the bids. It did not go smoothly: the range was cut from $108–$135 to $85–$95 and the shares were priced at $85, raising $1.67 billion [The Register, 19 August 2004]. Few large companies have copied the approach since.
- **Direct listings and SPAC mergers**, described in *Alternatives to the Traditional IPO* below, reach the market with no book-building at all.

Who gets the shares: institutions and retail

In a typical US IPO, most shares go to **institutional investors**. There is no legal minimum for retail investors; retail access usually comes through brokers that receive a small allocation from the underwriters, and IPO shares have traditionally been "reserved for wealthier brokerage clients and institutional investors" [CNBC, 2 July 2021]. That has been changing. Robinhood reserved **20% to 35%** of the shares in its own 2021 IPO for its customers [CNBC, 2 July 2021], and SpaceX's 2026 offering was reported to have used an institutional-to-retail ratio of 70:30.

Other markets write the split into the rules. Many European IPOs combine an *institutional offering* with a separate *public offering* to retail investors in the home country. Hong Kong specifies it precisely: under rules

in force since 4 August 2025, at least 40% of the shares must go to the book-built institutional tranche, and the public subscription tranche either starts at a minimum of 5% and is "clawed back" up to 35% if retail demand is very heavy, or is fixed at between 10% and 60% [Bird & Bird, 2025].

The lock-up

Before the IPO, founders, employees and venture capital funds own all of the company. If they could all sell on the first day, the flood of shares would swamp the market and the price would collapse. The **lock-up agreement** prevents this: insiders promise the underwriters not to sell for a fixed period, most commonly **180 days** [Investor.gov, *Lockup Agreements*]. Lock-ups are *contracts*, not law; securities law only requires that their terms be disclosed in the prospectus. The underwriters can release insiders early, and modern lock-ups are often staggered, releasing some shares early if the stock performs well. SpaceX's insiders reportedly agreed to a 366-day lock-up, other pre-IPO investors to 180 days.

The day a lock-up expires is a known date, and it is marked on every trader's calendar: a large block of shares suddenly becomes sellable, and prices often weaken around it.

Joining the index

A newly listed stock is not automatically part of the market indexes, and that matters a great deal. As the *Indexes* chapter of Part II explains, index funds *must* buy every stock in their index, in proportion to its weight. Inclusion in a major index therefore triggers large, price-insensitive buying.

Index providers traditionally made newcomers wait. The S&P 500 requires an IPO to have traded for at least **12 months** and to have positive earnings in its most recent quarter and over its most recent four quarters combined [S&P Dow Jones Indices, *U.S. Indices Methodology*]. In 2026 the arrival of several enormous IPOs put this under pressure. S&P Dow Jones Indices consulted on shortening the wait to six months and on exceptions for "mega-cap" companies, and on 4 June 2026 decided *not* to change the S&P 500's rules, stating that exceptions "should not be granted solely based on market capitalization" [S&P DJI, 4 June 2026]. Nasdaq went the other way: in spring 2026 it adopted a "fast entry" rule allowing a very large new listing to join the Nasdaq-100 after just **15 trading days**, with five trading days' notice. SpaceX joined the Nasdaq-100 under this rule, while its losses kept it out of the S&P 500. Critics pointed out the uncomfortable side effect: investors who bought at the IPO could sell to index funds that were obliged to buy only a few weeks later.

A gallery of outcomes

Company	IPO	Price and valuation	What happened
Amazon	May 1997	$18 per share	An unprofitable online bookseller at IPO; became one of the most valuable companies in the world
Pets.com	Feb 2000	$11 per share, raised $82.5m	Liquidated nine months later, shares at $0.19
Google	Aug 2004	$85 (Dutch auction, range cut from $108–$135), about $23bn	Priced below its hoped-for range; a long-term success
Facebook	May 2012	$38 (range raised twice), $104.2bn	Broke issue within days; later far exceeded its IPO price
WeWork	2019 (withdrawn)	$47bn private valuation, then talk of about $10bn	IPO pulled; SPAC listing 2021; bankrupt 2023
Snowflake	Sep 2020	$120 (range raised twice), $33.3bn	Doubled on day one, leaving roughly $3.75bn "on the table"

Company	IPO	Price and valuation	What happened
Rivian	Nov 2021	$78 (range raised), $66.5bn, with almost no revenue	Worth more than Ford on day one; later fell far below its IPO price
CoreWeave	Mar 2025	$40, below its $47–$55 range, deal cut	Weak book, then a strong rally within days
SpaceX	Jun 2026	$135, about $1.77tn, largest IPO ever	Rose about 19% on day one; valuation rests on a $28.5 trillion TAM story

What this means for exchange developers

The valuation debate happens before the exchange is involved, but IPO day itself lands squarely on exchange systems. A new symbol must be created in the reference data (see *Reference Data* in Part IV), with no trading history, so there is no previous close to anchor price collars or circuit breakers: the IPO price and the opening auction take that role. The opening auction may be delayed repeatedly while the indicative price settles and the lead underwriter confirms it is ready to open, so the auction logic must support extended, supervised call periods. Market-data volumes on a hot IPO's first morning can be extreme. And 180 days later, the lock-up expiry produces a predictable, scheduled surge in selling that risk and capacity planning should expect.

> **Key idea:** An IPO price is found, not calculated. Valuation models such as comparable multiples and discounted cash flow set a plausible range, but for young, high-growth companies nearly all of the value lies in distant, uncertain cash flows, and stories about total addressable markets fill the gap. Book-building, a customary rather than legally required process, then discovers what real investors will pay. Allocation rules decide who gets the shares, lock-ups keep insiders from selling too early, and index rules decide when forced buying arrives. Price it too high and the deal fails; price it too low and the company gives away capital it could have raised.

6.3 Initial Listing Standards

Every exchange publishes **initial listing standards**, minimum quantitative and qualitative thresholds a company must meet before its shares can begin trading. These typically combine several dimensions, and both NYSE and NASDAQ offer multiple listing tiers with different thresholds (NASDAQ's Global Select, Global Market, and Capital Market tiers, for example, from most to least stringent):

- **Minimum share price:** commonly a bid price of at least $4.00 at initial listing.
- **Market value of publicly held shares (public float):** a minimum aggregate dollar value of shares actually available for public trading, excluding insider- and affiliate-held blocks, illustratively in the tens of millions of dollars for the least stringent tiers and considerably higher for the most prestigious ones.
- **Minimum number of round-lot shareholders:** a floor on how widely the shares are already held, intended to ensure a genuine public market exists from day one rather than a handful of large holders.
- **Corporate governance requirements:** an independent board majority, an independent audit committee, and public financial disclosure obligations under the exchange's rules and the applicable securities laws.

(Exact numeric thresholds are revised periodically by each exchange and its regulator; treat the figures above as illustrative of the *kind* of requirement, not as current values to hardcode into any reference-data system.)

Meeting every quantitative threshold is necessary but, on some exchanges, not sufficient: as the *Indexes* section of Part II noted for S&P 500 committee discretion, initial listing approval can involve qualitative judgement about the business and its readiness for public markets, not a purely mechanical checklist.

6.4 Continued Listing: An Ongoing Obligation

Initial listing standards get most of the public attention, but **continued listing standards** matter more to exchange system developers, because they generate ongoing, automated compliance monitoring rather than

a one-time gate. A company that met every threshold at its IPO can fall out of compliance years later if its stock price declines, its market cap shrinks, or its public float narrows.

The most common continued-listing trigger is the **minimum bid price rule**: if a stock's closing price stays below $1.00 for 30 consecutive trading days, the exchange issues a formal deficiency notice. The company then has a **cure period**, commonly 180 days, to regain compliance (ten consecutive trading days at $1.00 or above), and in some cases a further 180-day extension if it meets other listing criteria. This is the direct, practical reason struggling companies execute a **reverse stock split** (see the *Corporate Actions* section of Part IV): consolidating, say, ten existing shares into one instantly multiplies the nominal share price by ten, curing a bid-price deficiency without changing the company's actual market value by a cent. A reverse split undertaken for this reason is a compliance action, not a statement about the business, and exchange systems must handle it exactly like any other corporate action (adjusting resting orders, historical price series, and reference data) regardless of the reason behind it.

Failure to cure within the allowed window leads to **involuntary delisting**: the exchange begins the formal process of removing the security, the company can appeal to a listing qualifications panel, and if the delisting proceeds, the shares typically continue trading, if at all, on the OTC (over-the-counter) markets described in Part I, with materially less liquidity, visibility, and investor protection than an exchange listing provided.

6.5 Voluntary Delisting

Not all delistings are compliance failures. A company can voluntarily delist because it has been **acquired** (its shares convert to cash or acquirer stock, as described in the *Corporate Actions* section of Part IV), because it has been **taken private** (a controlling investor or management buyout removes public shares from circulation entirely), or, more rarely, because it decides the costs of public-company reporting and exchange fees no longer justify the benefits of a listing. All of these still require an orderly unwind of open orders and positions in the symbol, exactly as described in the *Corporate Actions* section, whether the delisting is voluntary or forced.

6.6 Alternatives to the Traditional IPO

The underwritten IPO described in Part I, banks buy the offering and guarantee the company its proceeds, is not the only path onto an exchange.

Direct listings. In a **direct listing**, a company's existing shares begin trading directly on the exchange, in the classic form with no new shares issued, no underwriter guarantee, and no fixed offer price set in advance by a roadshow. Instead, the opening trade is established through the exchange's **opening auction** mechanism (see the *Opening and Closing Auction* section of Part II) exactly like any other trading day's open, just with unusually intense interest and no underwriter smoothing the process. Spotify's April 2018 listing on NYSE and Slack's June 2019 listing on NYSE were the pioneering examples that established direct listings as a credible alternative for companies that do not need to raise new capital and want to avoid underwriting fees and the traditional IPO discount. Because there is no underwriter-set price to anchor expectations, the exchange's auction-price-discovery mechanism carries unusually high scrutiny on a direct listing's first trade. (Since 2020 the SEC has also approved NYSE and Nasdaq rules for *primary* direct listings, in which the company sells new shares in that opening auction.)

SPAC mergers. A **Special Purpose Acquisition Company (SPAC)** is a shell company with no operating business that itself completes a conventional IPO, raising cash that is held in trust, with the explicit purpose of later merging with a private operating company to take it public. When the merger (a "**de-SPAC**" transaction) completes, the private company's shareholders receive shares in the (now renamed) public shell, and the target company is effectively listed without ever running its own IPO process. SPACs existed for decades as a niche structure but became a major share of total US listing activity in 2020–2021, before a wave of poor post-merger performance and increased SEC disclosure requirements sharply reduced the volume of new SPAC formations from 2022 onward. For exchange and reference-data systems, a de-SPAC transaction looks much like the symbol changes and delistings described in *Corporate Actions*, the shell's ticker and name are typically replaced by the operating company's (the surviving legal entity, and with it the SEC's CIK identifier, is often the shell itself), but compressed into a single scheduled event that must be coordinated precisely across trading, clearing, and market data simultaneously.

Key idea: An IPO is a financial event; a listing is a continuing regulatory relationship with a specific exchange, governed by initial standards to get in and continued standards to stay in. Reverse splits, delistings, direct listings, and SPAC mergers are all variations on the same underlying reference-data and corporate-action machinery described in Part IV, the trigger differs, but the exchange-side mechanics of updating symbols, adjusting orders, and coordinating the change across every downstream system are the same.

Glossary

The following definitions are written to be concise and standalone, useful as a quick reference after reading the document.

A

Automated Collar Expansion (ACE): This book's name for rules that, when an instrument's likely price lies outside its protective collar, pause only that instrument, keep collecting orders, and widen the collar in published steps until the indicative auction price fits, instead of either blocking a genuine repricing or trading at an absurd price. Real venues use their own names (Nasdaq's Halt Cross price protections, NYSE's auction-collar extension after LULD pauses, Xetra's extended volatility interruption). See *Price Collars*, Part III.

Adverse Selection: The risk a market maker faces when their quote is hit by a counterparty who has superior information about where prices are heading, causing the market maker to trade at a price that will quickly move against them. A market maker who is repeatedly adversely selected will lose money even while quoting at "correct" prices. MMP exists specifically to limit adverse selection damage.

Aggressive order: (also called a **taker**), an incoming order that immediately trades against resting orders. It "sweeps" the book.

Aggressor / Taker: The participant whose incoming order triggered a match by crossing the spread to meet a resting order. The aggressor "takes" liquidity that was already available. Contrast with *Maker*, the participant whose resting order was already in the book.

Assignment: The process by which an options clearing house (the OCC, in the US) selects which option writer(s) must fulfil the obligation created when a holder exercises. Assignment passes from the OCC to a clearing member and from the clearing member to a specific client, typically via random or FIFO allocation. See *Exercise*, *Pin Risk*.

Automated Market Maker (AMM): A smart-contract-based pricing mechanism used by decentralised cryptocurrency exchanges in place of an order book. Prices are set algorithmically from the ratio of two assets held in a liquidity pool, commonly via a constant-product formula, rather than by matching a buy order against a sell order. See *Decentralised Exchange (DEX)*.

Automatic Exercise: The OCC's practice of exercising any in-the-money option on a holder's behalf at expiry (by a threshold as small as $0.01 in-the-money) unless the holder has filed a contrary instruction. See *Exercise*.

Alternative Trading System (ATS): A trading venue that matches orders but is not a registered national securities exchange. Includes ECNs and dark pools. Subject to lighter regulation than exchanges in some jurisdictions.

Arbitrage: The simultaneous purchase and sale of the same (or equivalent) asset on different markets to profit from a price difference. Pure arbitrage is risk-free (buy cheap here, sell expensive there at the same moment); in practice, most arbitrage involves some timing or execution risk. Arbitrage is the mechanism by which prices on different venues are kept consistent, arbitrageurs quickly eliminate price discrepancies, making markets more efficient. **Latency arbitrage** is a specific form exploiting the time it takes for price changes

to propagate between venues.

Ask / Offer: The price at which a seller is willing to sell. The best (lowest) ask is the top of the sell side of the order book. The collection of all active asks forms the sell side of the book.

ATC (At-The-Close): An order TIF valid only during the closing auction.

ATO (At-The-Open): An order TIF valid only during the opening auction.

Auction / Call Auction / Uncross / Fixing: A trading mechanism where orders are collected over a period and then matched simultaneously at a single equilibrium price. Contrasts with continuous matching where orders match one at a time as they arrive.

Auction Imbalance: The excess of buy orders over sell orders (or vice versa) at the indicative uncross price during an auction. Published by exchanges to encourage offsetting orders before uncrossing.

Audit Trail: The complete, immutable, time-ordered record of every event in the exchange system, every order, fill, cancellation, and rejection, with precise timestamps. Required for regulatory reporting and replay-based recovery.

B

Big Bang: The 27 October 1986 deregulation of the London Stock Exchange, which abolished fixed commissions, ended the broker/jobber separation, permitted outside and foreign ownership of member firms, and replaced floor trading with the screen-based SEAQ system, all on a single day. The UK counterpart to the US's 1975 "May Day." See *May Day*.

Backwardation: A futures market in which near-dated contracts are more expensive than later-dated ones, so a calendar spread priced as near minus far is positive. The opposite of *contango*.

Basis: In derivatives and futures markets, the price difference between two related instruments, most commonly between the spot/cash price and a futures price on the same underlying, or between two futures contracts with different expiry dates. In the implied-order examples in this document (the *Implied Orders and Synthetic Liquidity* chapter of Part II), the spread price of −$2 between the January and February crude oil contracts is the basis between those two contract months: January is $2 cheaper than February. The basis is not fixed; it changes continuously as supply and demand for the near and far months evolve independently. **Basis risk** is the risk that the expected relationship between two instruments diverges unexpectedly, a spread trader who expected the two legs to move together may find they do not, leaving an unintended net exposure. See *Implied Order*, *Calendar Spread*.

Bear Market: A sustained decline of 20% or more from a recent market peak. Originates from the image of a bear swiping its paws downward. Contrast with *Bull Market*.

Best Ask: The lowest resting sell price in the order book, the price at which a buyer can trade immediately.

Best Bid: The highest resting buy price in the order book, the price at which a seller can trade immediately.

Best Execution: The regulatory obligation for brokers and investment firms to take all reasonable steps to achieve the best possible result for their clients when executing orders. "Best" considers price, execution costs, speed, likelihood of execution, and market impact simultaneously, not just the quoted price in isolation. Mandated by MiFID II in the EU and the SEC's duty of best execution in the US. Best execution is the regulatory foundation that makes smart order routing (SOR) necessary: brokers must demonstrate their routing decisions genuinely serve clients' interests, not just the broker's economics.

Bid: The price at which a buyer is willing to buy. The best (highest) bid is the top of the buy side of the order book.

Bid-Ask Imbalance: A measure of depth asymmetry: bid_depth / (bid_depth + ask_depth), computed within a symmetric price window around the mid. Values near 1 indicate heavy buying interest; values near 0 indicate heavy selling interest. Used as a short-term price direction signal.

Blue Chip: A large, financially sound, well-established company, the most prestigious tier of the equity market. The term originates from poker, where blue chips represent the highest denomination.

Bond: A standardised debt instrument. The issuing company borrows money and promises to pay periodic

interest (coupon payments) and return the face value (principal) at maturity. Bondholders are creditors, not owners, and are paid before equity holders in a bankruptcy. Bonds trade on secondary markets after issuance, allowing investors to exit before maturity. The financial term "bond" traces its roots back to the 14th century from the Old English word bindan and band, which eventually evolved into the standard English word "bind". The word was originally used to describe something that literally ties, fastens, or holds things together. Because a financial bond fundamentally operates as a formal, legally binding contract where an issuer promises to repay a loan with interest, the term stuck.

Book-Building: The customary way a conventional IPO is priced: the issuer and its underwriters publish a price range, collect indications of interest from institutional investors during a roadshow, revise the range, and set the final offer price the evening before trading starts. A process of price discovery, not a legal requirement.

Book Depth: The total volume (quantity of shares) resting near the top of the order book. A deep book absorbs large orders without significant price impact. A thin (or shallow) book moves quickly on even moderate order flow.

Book Snapshot: A periodic complete view of the current order book state (all price levels and their quantities) published by the exchange for subscribers who need to get up to speed.

Borrow Rate: The annualised fee charged to a short seller for borrowing shares from a lender. Easy-to-borrow large-cap stocks typically have borrow rates near zero. Hard-to-borrow, heavily-shorted, or illiquid stocks can carry rates of 5–50% or more per annum, applied daily to the short position. Rising borrow rates signal increasing short interest and decreasing availability of lendable shares, and are themselves a market signal.

Bracket Order: A strategy combining an entry order with both a take-profit LIMIT and a stop-loss STOP, typically implemented as an OCO pair.

Broker: An intermediary who executes orders on behalf of clients without trading for their own account. The word traces to Old French/Norse roots meaning someone who opens a cask and sells by the cup, a retail intermediary.

Bull Market: A sustained rise of 20% or more from a recent market trough. Originates from the image of a bull thrusting its horns upward. Contrast with *Bear Market*.

Buy-In: A remedy for failed settlement: if a seller cannot deliver securities, the buyer purchases them in the open market at the seller's expense.

C

Calendar Spread: A derivatives strategy involving the simultaneous purchase and sale of contracts on the same underlying instrument but with different expiry dates, for example, buy the March futures contract, sell the June futures contract. Used to profit from expected changes in the price difference (the "spread") between contract months. On CME and most futures venues it is also a listed instrument with its own order book, priced as near month minus far month; *buying* the spread means buying the near month and selling the far month, so the buyer profits when that difference rises. Spread prices are routinely negative. Requires cross-symbol coordination in the matching engine. See *Implied Order*.

Call auction: Synonym for auction, "call" refers to the fact that all participants are "called" to submit orders before a single price is determined.

Capital Appreciation: An increase in the market price of a share (or other asset) above the price paid. The primary way equity investors generate returns.

Capital Gain: The profit realised when an asset is sold for more than it was purchased for.

Cascade Cancel: When a COMBO order fails (any leg is cancelled or rejected), all remaining unfilled legs of the combo are automatically cancelled. Previously executed fills are not reversed.

CCP (Central Counterparty Clearing House): An entity that stands between buyer and seller in a trade, becoming the legal counterparty to both, eliminating direct counterparty credit risk.

Circuit Breaker: An automatic trading halt triggered when price movement exceeds a threshold within a time window, designed to prevent cascading automated trading crashes.

Clearly Erroneous Execution (CEE): A trade whose price deviates from a reference price by more than a published, price-tiered percentage threshold, making it eligible for cancellation (busting) or price adjustment under exchange rules. Reviewed execution-by-execution within a short time window (commonly 30 minutes); multi-venue events require coordinated rulings across exchanges. Distinct from a trade that is merely unwelcome to the participant who sent it, the test is an objective price deviation, not the sender's intent. See *Trade Busting and Clearly Erroneous Trades*, Part III.

Conformance Testing: The process by which a prospective exchange participant's trading system is verified, against a prescribed test script in a certification (UAT) environment, to correctly implement the exchange's protocol and expected behaviours before being granted production credentials.

Contango: A futures market in which later-dated contracts are more expensive than near-dated ones (common when the cost of storing the underlying is high), so a calendar spread priced as near minus far is negative. The opposite of *backwardation*.

Continued Listing Standards: The ongoing, ordinarily automated compliance thresholds (minimum bid price, market value of public float, shareholder count) a listed company must keep satisfying after its initial listing, distinct from the one-time *Initial Listing Standards*. Breach triggers a deficiency notice and cure period before involuntary delisting.

Crossed Market: A condition where the best bid on one trading venue is higher than the best ask on another venue for the same instrument, a transient artefact of fragmentation and quote-propagation latency across independent venues, and a theoretical risk-free arbitrage opportunity for whoever can act on it fastest. See *Locked Market*.

Cure Period: The window (commonly 180 days, sometimes extended) an exchange gives a listed company to regain compliance with a continued listing standard after a deficiency notice, before involuntary delisting proceedings begin.

Clearing: The process of confirming and recording a trade, and (via a CCP) guaranteeing its settlement.

Co-location: Placing a participant's trading servers physically inside the same data centre as the exchange's matching engine, minimising network round-trip latency to microseconds.

Collar Band / Price Collar: A price filter that rejects orders whose submitted price deviates too far from a reference price. Two distinct variants: the *static price collar* (compares against the last close) and the *dynamic price collar* (compares against the last trade). See those entries for details.

Combo Order: A single instruction to execute orders in multiple instruments simultaneously. Each component is a leg.

Conflation (Market Data): Merging consecutive market data updates for the same price level into a single message under high-load conditions. Reduces message volume at the cost of losing intermediate states.

Continuous Trading: The normal trading mode where orders match as soon as they arrive and a compatible counterparty is present. Contrasts with auction mode.

Contract Multiplier: For futures and options, the dollar (or other currency) value of a one-unit price move per contract. The E-mini S&P 500 has a multiplier of $50, a 1-point move in the index is worth $50 per contract. Essential reference data: a wrong multiplier affects every P&L and margin calculation.

Corporate Action: An event affecting a company's share structure, stock splits, dividends, mergers, delistings. Requires adjustments to all open orders, positions, and reference data in exchange systems.

Counterparty Risk: The risk that the other party to a trade defaults before settlement is complete. Cleared via CCP novation, which replaces bilateral counterparty risk with exposure to the CCP.

Coupon: The periodic interest payment on a bond. Named after the physical coupon strips that bond holders historically detached and redeemed for payment.

Crossing the Spread: Submitting an order at a price that matches an existing resting order, triggering an immediate fill.

Cum-Dividend: The period during which a share trades *with* entitlement to a declared dividend, the buyer receives the upcoming payment. A share trades cum-dividend from the dividend announcement up to (but not including) the ex-dividend date. After the ex-dividend date the share trades *ex-dividend* and the buyer is not

entitled to the payment. The price typically drops by approximately the dividend amount on the ex-dividend date.

CUSIP: A 9-character identifier for US and Canadian securities used in clearing and settlement. Analogous to ISIN.

Custody: The safekeeping of securities on behalf of investors by a broker or custodian bank, with records maintained at a central securities depository.

D

Dark Fibre: Unused optical fibre cable already laid in the ground but not yet carrying data traffic ("lit"). Trading firms and data providers lease dark fibre from infrastructure companies and run their own optical transceivers, creating private, dedicated network links between financial data centres. Dark fibre links are used between major exchange co-location sites (e.g., NYSE in Mahwah and NASDAQ in Carteret) to reduce cross-venue latency for arbitrage and hedging strategies.

Decentralised Exchange (DEX): A cryptocurrency trading venue that executes trades directly via smart contracts on a blockchain, with no central operator holding custody of participant assets and, commonly, no traditional order book, matching instead via an *Automated Market Maker*. Contrast with a *Centralised Exchange (CEX)*, which operates a conventional matching engine and custodies participant assets itself.

Decimalization: The switch from fractional dollar price quoting (eighths, then sixteenths) to decimal cent quoting in US equity markets, phased in between August 2000 and April 2001. Quoted spreads on liquid stocks roughly halved as a direct result. The direct historical motivation for Rule 612's sub-penny quoting floor. See *Tick Sizes and Fractional Ticks*, Part II.

De-SPAC: The merger transaction in which a Special Purpose Acquisition Company (SPAC) combines with a private operating company, resulting in the operating company becoming publicly traded under the (renamed) shell's listing. See *SPAC*.

Direct Listing: A method of going public in which a company's existing shares begin trading on an exchange via the opening auction mechanism, with no new shares issued, no underwriter guarantee, and no pre-set offer price. Contrast with a traditional underwritten IPO. Pioneered at scale by Spotify (2018) and Slack (2019), both on NYSE.

Dark Pool: A private trading venue where orders are not displayed in a public order book. Participants submit orders and are matched against other participants' orders, typically at the midpoint of the NBBO, with the trade only reported publicly after it occurs. Used by large institutional investors to trade without revealing their intentions and causing adverse price movement. Contrast with *lit markets* (public exchanges) where resting orders are visible to all. See *Regulatory Surveillance*.

DAY: An order TIF valid only for the current trading session.

Delivery versus Payment (DvP): The settlement principle that the transfer of securities and cash happen simultaneously and conditionally, neither is released without the other. Eliminates principal risk in settlement.

Depth (Market Depth): The total quantity of resting orders available at each price level. Deep markets can absorb large orders with minimal price impact.

Depth-of-Book (Level 2): Market data showing multiple price levels and their resting quantities, rather than only the best bid and ask.

Designated Market Maker (DMM): A firm assigned by an exchange to maintain fair and orderly markets in specific securities, with both privileges and obligations. NYSE's term; Nasdaq calls them Market Makers.

Determinism (Exchange): The property that given the same initial state and the same ordered input messages, the matching engine always produces identical outputs. Essential for audit trail replay and disaster recovery.

Discounted Cash Flow (DCF): A valuation method that estimates a company's future free cash flows and discounts each one back to today's money at a rate reflecting risk and the time value of money. For young, fast-growing firms most of the result usually sits in the *terminal value*, the lump that stands for all years beyond the forecast.

Dilution: The reduction in existing shareholders' ownership percentage when new shares are issued. Selling 20% of a company to new investors reduces existing owners to 80%.

Dividend: A cash payment made by a company to its shareholders, distributed from retained profits. Not guaranteed, the board of directors decides whether, when, and how much to pay. Companies that pay regular dividends are typically mature, profitable businesses with stable cash flows. High-growth companies often pay no dividend, choosing to reinvest profits in expansion. The key dates are: the *declaration date* (when the board announces the dividend), the *ex-dividend date* (buyers on or after this date do not receive the payment), the *record date* (the register of shareholders eligible to receive payment), and the *payment date* (when the cash is distributed).

Drop Copy: A real-time copy of all order lifecycle events for a specific participant, sent to a designated third party such as a clearing broker or risk system.

DTCC (Depository Trust and Clearing Corporation): The central clearing and settlement infrastructure for US equity markets. Its subsidiary DTC is the US central securities depository.

Dynamic Price Collar (Reference Price Filter): A pre-trade risk control that rejects any order whose submitted price deviates more than a configured percentage from the most recent traded price. Protects against algorithms that walk the price incrementally through a series of small trades. Contrast with *Static Price Collar*, which uses the last close as the reference. Together, the two collars provide overlapping protection against both sudden errors and gradual drift.

E

ECN (Electronic Communication Network): An electronic trading system that automatically matches buy and sell orders, typically with narrower spreads than exchanges but less regulatory oversight.

Equilibrium Price (Auction Price): The single price at which the maximum volume can trade in a call auction.

Equity: Ownership stake in a company. Equity holders (shareholders) have a residual claim on the company's assets and earnings after all creditors are paid.

ETF (Exchange-Traded Fund): A basket of securities (shares, bonds, commodities) that itself trades as a single share on an exchange.

Ex-Dividend Date: The date from which a stock trades without entitlement to a declared dividend. Buyers on or after this date do not receive the dividend.

Execution Algorithm (Algo): Software that breaks a large institutional order into smaller pieces and executes them over time to minimise market impact and achieve a target average price. Common types include VWAP (match the day's volume-weighted average price), TWAP (distribute uniformly over time), Implementation Shortfall (minimise the gap between decision price and execution price), and POV/In-Line (participate at a fixed percentage of market volume). Execution algorithms generate the majority of order flow on modern exchanges.

Exercise: An option holder's invocation of their right to buy (call) or sell (put) the underlying at the strike price. American-style options may be exercised any time up to expiry; European-style options only at expiry. See *Automatic Exercise*, *Assignment*.

F

Face Value (Bond): The principal amount of a bond, the amount the issuer promises to repay at maturity, and the basis on which coupon payments are calculated.

Failover: The process of switching from a failed primary system to a secondary (backup) system.

Fat Finger: Industry slang for an accidental trading error caused by mistyping an order parameter (quantity, price, etc.).

FIFO (First-In, First-Out): Within a price level, orders are filled in the order they arrived. Earlier arrivals have priority.

Fill: An execution, a match between a buy and sell order resulting in a trade. Partial fills consume part of an order; a complete fill consumes all of it.

FOK (Fill-Or-Kill): An order that must be completely filled immediately or cancelled entirely.

FIX (Financial Information eXchange): The industry-standard protocol for electronic order submission, used by most exchanges and brokers globally.

Flat: Having no open position in a symbol (net quantity = 0). Neither long nor short.

Floor Broker: Historically, a broker who executed trades on the physical exchange floor. The term persists in regulations and informal speech.

FPGA (Field-Programmable Gate Array): Reconfigurable hardware chips that can implement market data parsing or order routing in dedicated logic circuits, achieving nanosecond-level latency.

Front Running: Acting on advance knowledge of a pending client order to trade for one's own account before executing the client's order, then profiting from the price movement the client's order causes. Illegal under market manipulation regulations and a serious breach of fiduciary duty. Front running is detected by surveillance systems that flag cases where a participant's own trades immediately precede large client executions in the same direction.

Futures Contract: A standardised agreement to buy or sell a specified quantity of an underlying asset (commodity, index, currency, interest rate) at a predetermined price on a specified future date. Obligations are legally binding. Futures are exchange-traded, margined, and marked-to-market daily. Unlike equity ownership, futures do not represent ownership of an underlying asset, they represent an obligation about a future transaction.

G

Greenshoe (Over-Allotment Option): An option letting IPO underwriters sell up to 15% more shares than the base deal. If the price sags after listing they buy shares back in the market to support it; if it rises they exercise the option and buy the extra shares from the issuer at the offer price.

Gap (Market Data): A missing sequence number in a market data feed, indicating a lost message. Subscribers must request retransmission or resynchronise from the next full snapshot.

Gateway: The participant-facing interface to the exchange. Handles authentication, session management, and message translation.

Going Long: Owning an asset in expectation that its price will rise, so it can be sold later at a profit. You are "long" the asset. The term originates in physical commodity trading: a merchant who had purchased durable goods, grain, spices, metal, cloth, and was holding them in a warehouse was described as "long" in those goods. The word captured both *possession* (you own something tangible) and *duration* (durable goods last a long time and can be held through seasons or years). Being long in modern finance carries exactly the same meaning: you hold the asset and are exposed to its price over time. A long position profits when the price rises and loses when it falls.

Going Short / Short Selling: Selling an asset you do not currently own, typically by borrowing it from another party, with the intention of buying it back later at a lower price and returning it, pocketing the difference. The term originates in physical commodity trading: a merchant who had sold goods they did not yet possess, committing to deliver more than their warehouse held, was "short" of the goods. The same word family as "falling short," "short of supplies," or "shortage", deficient, insufficient, lacking. In the early forward markets of Amsterdam and London, a short seller would sell forward (promise future delivery), then purchase the goods in the market before delivery, hoping prices had fallen. Isaac Le Maire's 1609 campaign against VOC shares is the earliest recorded large-scale short selling operation. Today, a short position profits when the price falls (you buy back cheaper than you sold) and loses when it rises, in theory without limit, since a rising price has no ceiling.

GTC (Good-Till-Cancelled): An order TIF that persists across trading sessions until filled or cancelled.

GTD (Good-Till-Date): An order Time-In-Force variant that keeps an order active until it fills, is explicitly cancelled, or reaches a specified expiry date, whichever comes first. On the expiry date the order is automat-

ically cancelled. Provides the persistence of GTC without the open-ended risk of an order remaining active indefinitely. Requires the exchange scheduler to track each GTD order's expiry and issue the cancellation at the right time.

H

Heap: A data structure that gives O(1) access to the minimum (or maximum) element. Used in matching engines to efficiently maintain best price access.

High-Frequency Trading (HFT): Automated trading strategies that execute very large numbers of orders at extremely high speeds, typically holding positions for milliseconds or seconds rather than minutes or days. HFT firms invest heavily in low-latency infrastructure (co-location, microwave links, FPGAs) to gain speed advantages. Strategies include latency arbitrage, market making, and statistical arbitrage. Controversial because speed advantages can disadvantage slower participants; the subject of the IEX speed bump.

I

Iceberg Order / Hidden Order / Reserve Order: An order that shows only a small visible peak while hiding a large reserve. Each time the visible portion fills, the order replenishes from the reserve.

Imbalance: The difference between total buy and sell quantity at the equilibrium price. Expressed as a side (BUY or SELL) and a quantity.

Immediate-Or-Cancel (IOC): An order that fills as much as possible immediately and cancels any unfilled remainder. Never rests in the book.

Implementation Shortfall (IS) / Arrival Price Algorithm: An execution algorithm that minimises the difference between the *decision price* (the market price when the investment decision was made) and the actual average execution price. IS algos trade faster when the price moves against the position (urgency increases to avoid further shortfall) and slower when price moves favourably. More adaptive and sophisticated than VWAP or TWAP; preferred by quantitative funds whose models predict short-term price moves.

Implied Generation: A count of how many real orders an implied quote combines, minus one. A first-generation implied quote is built from two real orders; a second-generation quote uses a first-generation implied quote as an ingredient and so combines three. Venues restrict how many generations they compute because the work grows explosively. See *Multi-Layer Implied Orders and the Combinatorial Wall*, Part II.

Implied Matching: A technique used in derivatives markets where the exchange combines resting spread and outright orders (in different books) into a synthetic order in a third book, and lets incoming orders trade against it, all contributing orders executing together. For example: a resting spread order to buy March/sell June combined with a resting outright June bid creates an implied March bid. Implemented on CME Globex, ICE, and (as "synthetic matching") Eurex. Implied matching creates no new liquidity: it makes existing orders reachable from another book.

Implied Order: An order derived by the matching engine from a combination of existing spread and outright orders. Not submitted by any participant, computed from pre-existing orders and published in the relevant outright or spread book. When an implied order matches, all contributing orders execute simultaneously and atomically. If any contributing order is cancelled or filled by other means, the implied order shrinks or disappears in the same processing step. Implied orders never act as the aggressor, and at the same price real orders trade before them.

Implied IN: In CME's terminology, an implied order in the *spread* book created from orders in the outright books. Example: a January bid at \$74.40 and a February ask at \$76.60 together imply a Jan/Feb spread *bid* at $74.40 - 76.60 = -\$2.20$.

Implied OUT: In CME's terminology, an implied order in an *outright* book created from a spread order plus an outright order. Example: a January ask at \$75.00 and a Jan/Feb spread *bid* at −\$2.00 together imply a February *ask* at $75.00 - (-2.00) = \$77.00$.

Inactivation (Quote): Automatically cancelling or suspending the surviving leg of a two-sided quote the moment the other leg is filled. The market maker must re-quote both sides afresh within their re-quoting

window. Used in conservative quote refresh policies (Eurex-style). Protects the market maker from being left with a stale unhedged quote after their inventory position has changed.

Indicative Uncross Price: During an auction accumulation period, the price at which uncrossing *would* occur if matching happened at that moment. Recalculated after every order arrival and published as a signal to help participants decide whether to adjust their orders before the actual uncross.

Information Asymmetry: A situation where some market participants have access to information (faster data, better analytics) that others do not, giving them a trading advantage. Auctions reduce information asymmetry by letting all participants submit orders before any execution occurs.

Informed Flow: Order flow that originates from participants who have an informational advantage about near-term price direction, for example, participants who have seen relevant news before others. When a market maker is repeatedly hit by informed flow, they accumulate inventory at prices that are about to move against them. Informed flow is the root cause of adverse selection.

Initial Listing Standards: The quantitative (minimum share price, public float value, shareholder count) and qualitative thresholds a company must meet before an exchange will admit its shares to trading for the first time. Distinct from *Continued Listing Standards*, which apply on an ongoing basis thereafter.

Initial Margin: Collateral deposited when opening a position to cover potential losses. Calculated by the CCP based on the instrument's historical volatility and the position size.

Insider Trading: Trading on material, non-public information, for example, buying shares before a publicly unannounced merger is announced. Illegal in all major jurisdictions. The exchange's audit trail is a key source of evidence in insider trading investigations, as regulators can reconstruct exactly who traded, when, and at what prices relative to when news became public.

Instrument / Symbol: The specific financial product being traded. Each instrument has its own order book.

Internaliser: A broker-dealer that matches client orders internally against its own inventory or other clients' orders, rather than routing to an exchange. A form of OTC secondary trading.

IOC (Immediate-Or-Cancel): A time-in-force (and order type) where an order sweeps available liquidity at the limit price and any unfilled remainder is immediately cancelled. Never rests on the book

IPO (Initial Public Offering): The first sale of a company's shares to the general public, after which the shares are listed and traded on a stock exchange.

ISIN (International Securities Identification Number): A 12-character global identifier for a security, independent of the exchange it trades on. A single company has one ISIN regardless of where its shares are listed.

ITCH (NASDAQ TotalView-ITCH): NASDAQ's binary, message-based market data feed protocol for order book dissemination. ITCH publishes sequenced events such as add order, modify/replace, cancel/delete, executions, and auction/trade messages so subscribers can reconstruct the full limit order book deterministically from the stream. Official specification: NASDAQ TotalView-ITCH 5.0.

K

Kernel Bypass: Technology that allows a network application to communicate directly with network hardware, bypassing the operating system kernel and reducing latency from microseconds to sub-microsecond.

Kill Switch: An emergency control that immediately cancels all resting orders and quotes for a specific participant AND marks their gateway as inactive, preventing new order submission until the participant reconnects and re-authenticates. Triggered by the participant (emergency self-halt), the exchange operator, or automatically on gateway disconnect. Mandatory under most exchange regulations including MiFID II. Contrast with *Mass Cancel*, which cancels orders but leaves the gateway active.

L

Latency: The time delay between an action and its effect. In exchanges, latency is measured in microseconds or nanoseconds. Low latency is a competitive advantage.

Latency Arbitrage: Trading that profits from the brief period between when a price changes on one venue and when that change propagates to another venue.

Layering: A market manipulation practice: placing large orders to create a false impression of market depth, then cancelling them once the desired price movement occurs.

LCH: A major international clearing house, part of the London Stock Exchange Group. Clears interest rate swaps, equities, foreign exchange, and other products.

Leg: One component order within a combo order or spread strategy.

Leg Risk / Legging Risk: The risk that one leg of a combo order fills while another does not, leaving an unintended single-instrument position.

Level 1 Data: The best bid and ask prices and quantities only.

Level 2 Data (Market Depth): The full order book, all price levels and their quantities.

Limit Order: An order to trade at a specified price or better. May rest in the book if not immediately matched.

Limit Up-Limit Down (LULD): A US regulatory circuit breaker mechanism that pauses trading in an individual stock if its price moves outside a percentage band (the "price band") calculated from a reference price. The bands are tighter for liquid large-cap stocks and wider for smaller, more volatile ones. Trades outside the band are not allowed. If the best bid or offer sits exactly at the band (a "limit state") and does not recover within 15 seconds, a 5-minute trading pause begins. Implemented across all US equity trading venues.

Liquidity: The ease with which an asset can be bought or sold without significantly affecting its price. High liquidity = tight spread, large depth, easy trading.

Locate: The process of finding and reserving a source of borrowable shares before executing a short sale. Under US Regulation SHO, broker-dealers must have reasonable grounds to believe shares can be borrowed before accepting a short sale order. "Failing to locate" before shorting is called naked short selling, which is illegal in most jurisdictions.

Lock-Up: A contractual agreement, typically 180 days, under which insiders and pre-IPO investors promise not to sell their shares after an IPO. It is a contract with the underwriters, not a legal rule, and its expiry can put pressure on the share price.

Locked Market: A condition where the best bid on one venue equals the best ask on another venue for the same instrument, a transient artefact of fragmentation and quote-propagation latency. See *Crossed Market*.

Long Position: Owning a positive quantity of shares. You profit if the price rises. Expressed as a positive number P&L ledger.

Lot: The standard unit of quantity for an instrument.

M

Maintenance Margin: The minimum collateral balance that must be maintained in a margin account. Falling below this level triggers a margin call.

Maker: The participant whose resting order was already in the book when a fill occurred. Contrast with *Aggressor/Taker*.

Margin Call: A demand from a clearing house or broker for a participant to deposit additional collateral to restore their margin account to the required level.

Mark-to-Market: The daily revaluation of positions at current market prices, with cash payments made to reflect daily gains and losses. The mechanism by which variation margin is calculated.

Market capitalisation (market cap): The total market value of all a company's outstanding shares, calculated as share price multiplied by the total number of shares in existence. If Apple has approximately 15.4 billion shares outstanding and each trades at $190, Apple's market cap is roughly $2.9 trillion [1]. Market cap is the most widely used shorthand for a company's size. When rankings refer to "the world's largest exchange by listed market cap," they are summing the market caps of every company listed there.

Market Fragmentation: The distribution of trading volume for a single instrument across multiple competing venues, exchanges, dark pools, ATSs, and internalisers. Modern equity markets are highly fragmented; in the US, AAPL may trade simultaneously across a dozen registered exchanges plus numerous alternative venues. Fragmentation improves competition and reduces fees but complicates order routing and best-execution analysis. Regulatory frameworks like Regulation NMS (US) and MiFID II (EU) were introduced partly in response to fragmentation.

Market Impact / Slippage: The adverse price movement caused by a large order sweeping through multiple price levels.

Market Impact Estimation: The process of computing, before order submission, the average price you would pay (or receive) by sweeping through available book levels for a given order size. Derived from the cumulative depth profile. Used by execution algorithms to size order slices and choose between aggressive execution and passive accumulation.

Market Maker: A professional participant obligated to continuously provide both buy and sell prices, ensuring liquidity for other participants.

Market Maker Protection (MMP): An exchange-provided mechanism that automatically cancels all of a market maker's resting quotes when fills arrive at a rate exceeding a configured threshold within a rolling time window. Protects market makers from being rapidly picked off by participants with superior information (adverse selection). After MMP fires, the market maker enters a protection period before re-quoting. Parameters (fill count, time window) are configured per market maker per symbol.

Market Order: An order that attempts immediate execution against available liquidity at the best obtainable prices. It prioritises execution certainty over price certainty, but execution is still subject to exchange state, available liquidity, price collars, and risk controls. A market order submitted during a halt, against an empty book, or rejected by a pre-trade risk check will not fill.

Mass Cancel: A participant-initiated message type that cancels multiple resting orders simultaneously, all orders for a symbol, all orders of a given type, or all orders system-wide. The gateway connection remains active after a mass cancel; the participant can submit new orders immediately. Contrast with *Kill Switch*, which inactivates the gateway and requires re-authentication.

Matching Engine: The core software that manages order books and matches buy and sell orders to produce trades.

Maturity (Bond): The date on which a bond's issuer must repay the face value to the bondholder.

May Day: 1 May 1975, the date the SEC abolished fixed brokerage commissions on the NYSE, ending nearly two centuries of fixed-rate trading and creating the discount-brokerage industry. The US counterpart to the UK's 1986 "Big Bang." See *Big Bang*.

Microwave Link: A radio communications link using microwave frequencies. Between financial data centres, microwave links provide lower latency than fibre-optic cables because radio waves travel faster through air than light through glass.

Mid Price: The average of the best bid and best ask: (best_bid + best_ask) / 2.

Midpoint Peg Order: An order whose price continuously tracks the current mid price (the average of the best bid and best ask). Executes only when a counterparty arrives whose order is also willing to trade at the midpoint. The mid is a *better* price for both parties than the quoted bid or ask, the buyer pays less than the ask, the seller receives more than the bid; the spread is shared rather than fully paid. Provides price improvement at the cost of uncertain execution timing: there is no guarantee a counterparty will appear. Common in dark pools; also supported on IEX on the lit market. Never competes in the regular price-time priority queue, maintained as a separate midpoint matching layer.

MMP Threshold: The fill count and time window that together trigger Market Maker Protection. For

example, "5 fills within 1 second." If this threshold is exceeded, the exchange automatically cancels all of the market maker's resting quotes. The threshold is negotiated per market maker, per symbol, and finding the right value is a key parameter of market making strategy.

Monotonic: Strictly non-decreasing. A monotonic sequence is one where each value is equal to or greater than all previous values. A strictly monotonic sequence is one where each value is strictly greater.

N

Naked Short Selling: Selling shares short without first locating and arranging to borrow them. The seller delivers nothing at settlement, creating a "fail to deliver." Illegal in most jurisdictions under short sale regulations (Regulation SHO in the US). Distinguished from covered short selling, where shares have been located and borrowed.

Nanosecond: One billionth of a second (10 seconds). Modern matching engines record timestamps at nanosecond precision.

NBBO (National Best Bid and Offer): The best available bid and ask prices aggregated across all US exchanges, as required by Regulation NMS. Brokers must offer clients execution at or better than the NBBO.

NAV (Net Asset Value): The total value of a fund's holdings divided by the number of shares outstanding. For mutual funds, NAV is computed daily using the official **closing price** of each holding, one reason the closing price matters so much.

Novation: The legal process by which a CCP replaces the original buyer-seller relationship: the CCP becomes buyer to the seller and seller to the buyer, eliminating bilateral counterparty risk.

NTP (Network Time Protocol): A protocol for synchronising computer clocks over a network. Basic NTP achieves millisecond accuracy; higher-precision variants achieve sub-millisecond.

O

OCC (Options Clearing Corporation): The central clearing house for equity options in the US.

Odd Lot: An order or execution for a quantity that is not a whole multiple of the standard round lot size for that instrument (commonly 100 shares for US equities). Historically excluded from consolidated NBBO and tape data in US equities, a practice being revised under the SEC's market-data-infrastructure rules. See *Round Lot*.

OCO (One-Cancels-Other): Two linked orders where filling either automatically cancels the other.

OHLCV: Open, High, Low, Close, Volume, the five standard summary statistics recorded for each trading session (or any time period). Open: the first traded price. High: the highest traded price. Low: the lowest traded price. Close: the last traded price (the official closing price in a closing auction). Volume: total shares traded. OHLCV data forms the basis of almost all price charts and historical market analysis.

Open Outcry: The historical method of trading on exchange floors, where traders shouted bids and asks and used hand signals in a sunken circular area called a pit. Largely replaced by electronic trading.

Options: Contracts that give the buyer the right, but not the obligation, to buy (a **call option**) or sell (a **put option**) an underlying asset at a specified price (the **strike price**) before or on a specified date (the **expiry date**). The seller of an option takes on the corresponding obligation. Options are priced using models (Black-Scholes being the most famous) that account for time to expiry, volatility, interest rates, and the distance between the current price and the strike. Cboe is the world's largest options exchange.

Order: An instruction to buy or sell a quantity of an instrument at a specified price or better.

Order Book: The central data structure of a matching engine, all resting buy and sell orders for a symbol, organised by price.

Order ID: A unique identifier assigned to each order upon submission. Must be unique across the entire system.

OTC (Over-the-Counter): Trading that occurs directly between two parties without going through an

exchange. OTC trades are less transparent and subject to different regulations than exchange-traded transactions.

OUCH (NASDAQ OUCH): NASDAQ's high-performance binary order entry protocol used by member firms and low-latency trading systems to submit, modify, cancel, and manage orders directly at the matching engine. OUCH is session-based and message-oriented, with exchange acknowledgments and execution/cancel responses that let clients track the full order lifecycle deterministically. Official specification: NASDAQ OUCH 5.0.

P

P&L (Profit and Loss): The financial gain or loss on a trading position.

Passive Order: See *Resting Order*

Payment for Order Flow (PFOF): A practice in which retail brokers receive payment from wholesale market makers in exchange for routing client order flow to those market makers for internalisation rather than to lit exchanges. Market makers pay for retail flow because retail orders have lower adverse selection risk. Effectively banned in the UK since 2012, and banned EU-wide from 30 June 2026 under the 2024 MiFIR review. Legal but controversial in the US, where it subsidises zero-commission brokerages but raises concerns about conflicts of interest and reduced price discovery. See *Best Execution*, *Internaliser*.

Pin Risk: The risk faced by an option writer when the underlying closes at expiry very close to the strike price, leaving the writer uncertain whether automatic exercise and assignment will occur until after markets have closed, with any resulting delivery obligation priced at the strike regardless of where the underlying opens the next session. See *Exercise*, *Assignment*.

Pit: The sunken, octagonal or circular physical trading area on an exchange floor where open outcry trading happened. CME Group operated prominent futures pits in Chicago. Largely dormant today.

Portfolio: A collection of investments held by an investor, typically diversified across asset types (equities, bonds, etc.) to manage risk and return.

Position: A participant's current holding in an instrument, positive (long) if they own more than they have committed to deliver; negative (short) if they have committed to deliver more than they own; zero (flat) if both sides balance. Position tracking is the clearing system's primary responsibility.

Pre-Trade Risk Controls: Checks applied to orders before they reach the matching engine, quantity limits, notional limits, fat-finger filters, credit checks, and rate limiting. The gateway is typically the enforcement layer.

PRE_OPEN: Session phase before the opening auction. Orders are accepted and rest on the book, but no matching occurs.

Presence Obligation: A market maker's contractual requirement to have live two-sided quotes resting in the book for a minimum percentage of the trading session, commonly 85% or more. Prevents market makers from only quoting on easy days and disappearing on volatile ones when liquidity is most needed.

Price Discovery: The process by which the market determines the current fair price of an asset through the interaction of buyers and sellers. A well-functioning exchange enables efficient price discovery: prices reflect all currently available information and update rapidly as new information arrives. Price discovery is one of the three core promises every exchange makes. Poor price discovery, where the traded price diverges significantly from fair value for extended periods, is a sign of market dysfunction.

Price Level: All resting orders at the same price on the same side of the book.

Price-Time Priority: The matching rule: better prices fill first; at the same price, earlier arrivals fill first.

Primary Market: Where new securities are issued and sold for the first time. The company (or government) receives the proceeds.

Primary Site: The active, live data centre running the production matching engine.

Private Company: A company whose shares are not publicly traded, held only by founders, employees, and private investors.

Prospectus: The disclosure document a company must publish before offering securities to the public. In the EU it is governed by the Prospectus Regulation (EU) 2017/1129 and approved by a national competent authority; in the US it forms part of the S-1 registration statement.

Pro-Rata Allocation: An alternative to price-time priority where fills at a price level are distributed proportionally among all resting orders at that level. Common in some futures markets.

Protection Period: The window of time after MMP fires during which a market maker has no active quotes and is expected to assess market conditions before deciding whether and at what prices to re-enter. The duration is typically a few seconds and is defined in the market maker agreement.

PTP (Precision Time Protocol, IEEE 1588): A network clock synchronisation protocol achieving sub-microsecond accuracy. Used in exchange infrastructure to ensure consistent timestamps across distributed systems.

Public Company: A company whose shares are listed on a stock exchange and available to any investor.

Q

Quote: A two-sided order submitted by a market maker containing both a bid (buy) and an ask (sell) simultaneously. Unlike a regular order, the two legs are linked, what happens to one (a fill, a cancellation) triggers a defined response on the other according to the quote refresh policy.

Quote Leg: One side (bid or ask) of a two-sided market maker quote. Filling one leg triggers the quote refresh policy for the other leg.

Quote Refresh Policy: The rule governing what happens to the surviving leg of a two-sided quote when the other leg is filled. Three main variants: (1) cancel both sides immediately, the most conservative, used by Eurex-style inactivation; (2) cancel only the filled side, leave the other active; (3) leave both active. The choice reflects the market maker's balance between speed of re-entry and risk of holding stale inventory.

Quote Stuffing: A market manipulation practice where a participant rapidly submits and cancels a very large number of orders to consume exchange bandwidth, slow down competitors' systems, and create artificial confusion in market data. A form of denial-of-service abuse in electronic markets.

R

Ratchet: The mechanism in a trailing stop that advances the stop price in the favourable direction but freezes it when the market reverses.

Rate Limiting / Throttling: A control that limits the number of orders a participant can submit per unit time. Prevents denial-of-service conditions from algorithmic misfires.

Re-quoting Obligation: A market maker's contractual requirement to post a fresh two-sided quote within a specified maximum delay after either leg of their previous quote is filled or after MMP fires. Failure to re-quote within this window counts against the presence obligation and may trigger penalties. The window is typically measured in milliseconds to low seconds.

Realized P&L: Profit or loss that has been "locked in" through a trade that reduced an open position. Once realized, it cannot be reversed by subsequent price moves.

Reference Data / Instrument Master: The configuration data describing a tradeable instrument, tick size, price scale, session schedule, contract multiplier, trading status, expiry date, position limits. Read by every exchange component; an error propagates system-wide. Treat it with the same rigour as code: version-controlled, tested, applied atomically.

Regulation NMS: A US Securities and Exchange Commission regulation requiring that equity orders be executed at the best available price across all exchanges (the NBBO). A primary driver of US market fragmentation.

Regulation SHO: A US Securities and Exchange Commission rule governing short sales in equity markets. Key requirements: broker-dealers must have a reasonable belief shares can be borrowed before accepting a short sale order (the "locate" requirement); persistent fail-to-deliver situations must be closed out; short sales

must be marked as "short" in order records. Adopted in 2005 to address concerns about abusive naked short selling.

Replay (Exchange): Replaying a recorded sequence of input messages through the matching engine to reconstruct past market states. Requires the engine to be deterministic.

Reserve Refresh Priority: The queue position rule for iceberg replenishment. Most exchanges place a newly replenished iceberg peak at the back of the queue at its price level, equivalent to a brand-new arrival, rather than preserving the original queue position.

Resting Order / Passive Order: An order that has been accepted by the exchange and is waiting in the book for a counterparty.

Retained Earnings: Profits kept within the business rather than distributed to shareholders. A source of self-funding for company growth.

Rolling Window (MMP): The time period over which fills are counted for Market Maker Protection purposes. Fills older than the window are discarded from the count; only fills within the current window matter. For example, a 1-second rolling window means: "if more than N fills have arrived in any sliding 1-second period, MMP fires."

Round Lot: The standard trading unit for an instrument (commonly 100 shares for US equities), used as the basis for distinguishing a normal order from an *Odd Lot*.

Rule 612 (Sub-Penny Rule): The Regulation NMS provision, adopted 2005, prohibiting exchanges, ECNs, and market makers from displaying or accepting quotations in NMS stocks priced at $1.00 or more in increments finer than $0.01. Stocks priced below $1.00 may be quoted in sub-penny increments. See *Tick Sizes and Fractional Ticks*, Part II.

S

Secondary Market: Where existing securities are traded between investors. The issuing company does not receive proceeds. Stock exchanges are secondary markets.

Secondary Site / Backup Site: A standby data centre that can take over exchange operation if the primary site fails.

Securities Lending / Stock Borrow: The temporary transfer of securities from a lender (typically a long-term investor or custodian) to a borrower (typically a short seller) in exchange for collateral and a lending fee (borrow rate). Short sellers must borrow shares before selling short. The lender retains economic ownership (receives manufactured dividends and can recall the shares) but transfers legal title temporarily. Recall risk, the lender demanding shares back at an inconvenient time, is a key risk for short sellers.

S-1 (Form S-1): The registration statement a US company files with the SEC under the Securities Act of 1933 before an IPO. It contains the prospectus, audited financials, risk factors and the *use of proceeds*. Foreign issuers use the equivalent Form F-1.

SEDOL: A 7-character UK security identifier used in settlement and clearing. Analogous to CUSIP.

Self-Match Prevention (SMP): A mechanism that detects when a participant would trade against their own orders and applies a cancellation policy.

Sequence Number: A monotonically increasing counter attached to events (in a drop copy or message feed) to enable detection of missed events and ordered replay.

Session State Machine: The formal model of an exchange's trading day phases (PRE_OPEN, OPENING_AUCTION, CONTINUOUS, CLOSING_AUCTION, CLOSED) and the permitted transitions between them.

Securities Information Processor (SIP): The consolidated, publicly distributed feed aggregating trade and quote data from every registered US exchange into a single tape. Contrast with a *proprietary direct feed*, which an individual exchange sells separately, typically with lower latency and richer content than the SIP. See *Market Data Economics*, Part IV.

Settlement: The final transfer of securities from seller to buyer and cash from buyer to seller. Legally

completes the trade. In the US, equity settlement currently occurs on T+1.

Settlement Method (Derivatives): Whether a futures or options contract settles by cash payment or physical delivery of the underlying asset. Determines post-expiry processing required by the exchange and clearing house.

Shadow Replication / Shadow Mode: An architectural pattern for high-availability exchange systems. The secondary site receives and processes all input messages in parallel with the primary, maintaining an up-to-date copy of the order book, but does not publish outputs or accept participant connections. If the primary fails, the secondary's in-memory state is already current and it can begin accepting inputs and publishing outputs with minimal failover time. More common in production than true active-active matching.

Share / Stock: A single unit of equity ownership in a company. Each share represents a fractional claim on the company's assets, earnings, and votes.

Slippage: The difference between the expected fill price and the actual average fill price, caused by executing against multiple price levels in the book. Large orders in thin books experience more slippage.

Smart Order Router (SOR): Software that evaluates multiple trading venues and routes orders to achieve the best overall execution, balancing price, fees, available depth, and speed.

SmartNIC / Ultra-Low-Latency NIC: A specialised network interface card designed for trading and other latency-sensitive applications. Unlike commodity Ethernet cards, SmartNICs include an on-card kernel bypass networking stack (such as Solarflare's OpenOnload or Mellanox's RDMA), hardware timestamping of incoming packets to nanosecond precision, and CPU offload for networking tasks. Examples include the AMD Solarflare SFN series and NVIDIA Mellanox ConnectX series, widely deployed in exchange co-location environments.

Snapshot (Persistence): A complete dump of the matching engine's state (all resting orders, positions, key data) taken periodically to reduce recovery time by limiting the amount of write-ahead log that must be replayed.

SPAC (Special Purpose Acquisition Company): A shell company with no operating business that completes its own IPO to raise cash held in trust, with the purpose of later merging with a private operating company to take it public without a traditional IPO process. See *De-SPAC*.

Specialist: NYSE's historical term for the designated firm responsible for maintaining fair and orderly markets in a specific stock, including maintaining the physical order book. The modern equivalent is the Designated Market Maker (DMM).

Speed Bump: A deliberate artificial delay applied to all incoming orders to eliminate the advantage of being marginally faster than other participants. Pioneered by IEX.

Split-Brain: A failure mode in distributed systems where two nodes both believe themselves to be the active primary, leading to conflicting actions.

Spoofing: A market manipulation practice: placing orders with no intention of trading to move prices, then cancelling before execution. Illegal under market abuse regulations.

Spread: The difference between the best ask and the best bid. Market makers earn the spread; participants pay it as the cost of immediate trading.

State Machine: A formal model consisting of a finite set of states and explicit rules about which transitions between states are allowed.

Static Price Collar (Fat-Finger Filter): A pre-trade risk control that rejects any order whose submitted price deviates more than a configured percentage from the last official close price. Designed to catch obvious fat-finger errors, an order at $15.00 on a stock trading at $150.00 is almost certainly a decimal error. Because the reference is the previous close, the static collar is stable throughout the trading day. Contrast with *Dynamic Price Collar*, which tracks the most recent trade instead.

Stop Order: A conditional order that is dormant until the market price reaches the stop price, then converts to another order type.

Stop Price: The trigger price on a stop or stop-limit order. The order remains dormant until the market's last trade price reaches or crosses the stop price, at which point it activates and enters the book (as a market

or limit order, depending on type). A buy stop has a stop price above the current market; a sell stop has a stop price below it.

Stop-Limit Order: A stop order that converts to a limit order when triggered. Provides price protection but may not execute if the market gaps.

Stop-Loss: A sell stop order used to automatically exit a losing long position if the price falls to a specified level.

Surplus: The absolute difference between cumulative buy and sell quantity at the equilibrium price, the quantity that cannot be matched.

Sweeping: The process of an aggressive order filling against resting orders at successive price levels.

T

T+1 / T+2 Settlement: Settlement occurring 1 or 2 business days after the trade date. The US moved from T+3 to T+2 in 2017 and to T+1 in 2024.

T+2 Settlement: Settlement occurring two business days after the trade date. The US standard until 2024; most US equities now settle T+1. T+2 remains the standard in many other markets.

Tick: The minimum price movement for an instrument.

Tick Count / Tick-Based Price: A price represented as an integer number of minimum increments, rather than a decimal. Tick counts are exact; floating-point decimals are not.

Tick Size: The value of one tick, the minimum price increment for an instrument.

Tick Size Pilot Program: A US SEC study (October 2016 – October 2018) that widened the tick size to five cents for roughly 1,200 small-capitalisation stocks to test whether coarser ticks improve market-making economics and liquidity for thinly traded names. Results were mixed: quoted spreads and costs for small trades rose, displayed size at the best prices rose sharply, but the hoped-for improvement in overall liquidity and capital formation did not appear, and no permanent wider-tick regime was adopted. See *Tick Sizes and Fractional Ticks*, Part II.

Tick-to-Trade Latency: The time from when a market data message leaves the exchange to when an order based on that message is received by the exchange. A key performance metric for market makers and HFT firms.

Ticker / Ticker Symbol: The abbreviated code identifying a tradeable instrument (e.g., AAPL for Apple Inc.). Named after the mechanical stock ticker machine that printed trade prices on paper tape using telegraph signals in the late 19th and early 20th centuries.

Ticker Tape: The narrow paper strip printed by the stock ticker machine, showing a continuous stream of trade symbols, prices, and volumes. The source of the term "tick" (minimum price movement) and related concepts.

Time-In-Force (TIF): The attribute specifying how long an order remains valid (DAY, GTC, IOC, FOK, ATO, ATC).

Top-of-Book (Level 1): Market data showing only the best bid price, best ask price, and their quantities. The minimum information needed to understand the current market.

Total Addressable Market (TAM): The total revenue available if a company captured 100% of its market. Often narrowed to the serviceable addressable market (SAM) and the share realistically obtainable (SOM). Popular in growth-company IPO pitches, and notorious for being stretched.

Trade: An executed match between a buy and sell order. Also called a fill or execution.

Trailing Stop: A stop order whose trigger price automatically advances in the favourable direction as the market moves, protected by a fixed trail offset.

TWAP (Time-Weighted Average Price Algorithm): An execution algorithm that distributes a large order evenly across equal time intervals, regardless of trading volume. Simple and predictable, but less adaptive than VWAP. Used when a stock has no reliable volume profile or when the trader wants mechanically

consistent participation. Performance is measured against the average of prices during the execution window, not the overall day's VWAP.

Two-Sided Quote: A market maker's simultaneous bid and ask for the same instrument. Both sides must be live at the same time to fulfil the two-sided quoting obligation. A one-sided quote (only bid or only ask) is a contractual breach of market maker obligations.

U

UUID (Universally Unique Identifier): A 128-bit identifier designed to be unique without central coordination. UUID v4 is randomly generated; UUID v1 incorporates the current time and network address.

Underpricing: Setting an IPO offer price below what the market will pay, visible as a first-day price jump. The gap multiplied by the number of shares sold is called money *left on the table*.

Uncross The single atomic batch execution that occurs at the end of an auction phase. All crossable orders execute at the **equilibrium price** simultaneously.

Unrealized P&L The theoretical profit or loss on an open position if it were closed at the current market price. Changes continuously as the market moves. Becomes realized P&L when the position is closed.

V

Variation Margin: Daily cash payments reflecting mark-to-market gains and losses on open positions. Prevents losses from accumulating to unmanageable levels before settlement.

Venture Capital (VC): Private investment firms that provide funding to early-stage companies in exchange for equity stakes, before those companies are large enough to go public.

VIX (Volatility Index): A real-time index calculated by Cboe from the prices of S&P 500 options, representing the market's expectation of 30-day price volatility in the S&P 500. Commonly called the "fear gauge", when markets are uncertain or falling sharply, participants buy put options for protection, driving up option prices and therefore the VIX. Values above 30 typically indicate high market stress; values below 20 indicate relative calm. Derivatives on the VIX itself trade on Cboe.

VWAP (Volume-Weighted Average Price): The average price of a position weighted by the quantity traded at each price. Used as cost basis for P&L calculation. VWAP $= \frac{\sum(\text{price}_i \times \text{qty}_i)}{\sum \text{qty}_i}$\$

VWAP Algorithm: An execution algorithm that slices a large order and executes it throughout the day in proportion to expected trading volume, more during high-volume periods (open, close) and less during low-volume periods (mid-day). The goal is to achieve an average execution price close to or better than the day's volume-weighted average price. The most widely used institutional execution benchmark. Distinct from *VWAP (Volume-Weighted Average Price)*, which is a measurement; the VWAP algorithm is the execution strategy aimed at matching that measurement.

W

Wash Trading / Wash Trade: A transaction where the same participant is on both sides, generating artificial trading volume with no real change of ownership. Illegal in all major jurisdictions under market manipulation regulations (the EU's Market Abuse Regulation, the US SEC's Rule 10b-5, and others). Also called a wash sale. Sometimes performed accidentally, see *Self-Match Prevention (SMP)*, but when deliberate, it is a form of market abuse used to inflate trading volume figures or create false impressions of liquidity.

Write-Ahead Log (WAL): A persistent, append-only log of all input messages to the matching engine. Written before processing; used for recovery and replay. The source of truth from which all derived state (the in-memory order book) can be reconstructed.

Z

ZeroMQ (ZMQ): A messaging library providing efficient pub/sub, push/pull, and other communication patterns. Commonly used as the message bus in exchange systems. Uses a broker-less PUSH/PULL and PUB/SUB topology. No external message queue server is required.

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Exchanges own technical references

Publicly available technical specifications and documentation provide exact structural logic and algorithmic details for combo and implied/synthetic orders across major electronic matching engines.

CME Globex Matching Engine & Implied Logic

CME Group provides open-access engineering wikis that map out their continuous multi-leg matching models.

- **Implied Orders Functionality:** To read the explicit state constraints, calculation boundaries, and engine generation rules for "Implied-In" and "Implied-Out" routing structures, visit the CME Globex Implied Orders Documentation.
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Cboe details its execution logic for multi-leg derivative allocations, net premium sorting, and atomicity verification.

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NYSE Pillar (Equity Trading Platform)

The core documentation for understanding order behavior, priority categories, and amendment rules across the NYSE (New York Stock Exchange) platform

- Pillar is NYSE technology platform which enables members to access NYSE equities and options markets using standard protocols, NYSE Pillar
- The structural and architectural details are broken down in the official NYSE Pillar Functional Differences Guide. This resource outlines how market collars, auction imbalances, and continuous trading interactions operate inside the core matching engine.
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Closing auction volume: The share of daily volume executed in US closing auctions varies by year, instrument, and calendar (it spikes on index rebalancing days); the figures in the text are from BMLL's 2024 analysis cited above. See The shifting dynamics of the NYSE Closing Auction

Back-Cover Text

You can write production-grade software in many domains without ever asking what a "spread" really is, why a matching engine must be deterministic, or what happens when a market suddenly halts.

Financial exchanges are not one of those domains.

How a Financial Exchange Works is a practical conceptual guide for developers, architects, product owners, QA engineers, and operations teams who need to understand market structure fast, without wading through rulebooks before they can ship. It explains the language, mechanics, and failure modes of modern markets in plain English: from bids, asks, and order books to auctions, implied matching, risk controls, clearing, settlement, surveillance, and market data economics.

This second edition is significantly expanded and updated, with deeper treatment of exchange microstructure, implementation-relevant architecture, and the real operational realities teams face in live systems.

Inside you will learn:

- How exchanges create price discovery, liquidity, and fairness
- How orders, priority rules, and matching logic produce trades
- Why tick sizes, auctions, and market fragmentation matter in practice
- How risk controls, conformance testing, and post-trade processes keep markets stable
- Where real-world edge cases appear, and what they imply for system design

No hype. No hand-waving. No prerequisite finance degree.

Just the map you need to stop translating jargon and start reasoning clearly about the system you are building.

About the Author

Johan Persson is a software engineer and musician with over 30 years of experience in high-performance, safety-critical systems. He has worked in multiple fields in software design and among them modern financial trading systems, as well as with thruster design for satellite control systems. Johan is passionate about making complex systems understandable and accessible and actually enjoys writing documentation. Johan lives in Sweden with his family and enjoys playing banjo (5-string, of-course!), cycling, wood-working, and when time allows, doing electronics design for analog computers.

As a companion to this book Johan has also written an educational exchange platform `EduMatcher` which implements many of the techniques discussed in this book. While out of necessity it is simplified compared with real exchanges it is still a surprisingly complete multi-process, message-bus based trading platform that can run on a laptop. It uses its own protocol suit with names that is a wink to the fintech industry; ALF, BALF, CALF, RALF, and LALF, with ALF=**AL**most **F**ix, BALF=**B**inary **ALF**, CALF=**C**hannel **ALF**, RALF=**R**econcilliation **ALF**, LALF=**L**ogging **ALF**. It makes an excellent companion to run while reading this book!