

# Introduction

There was a time when investors all over the world were satisfied with holding periods that could have lasted a lifetime; indeed, there was this utopian view that stocks were on a path of ever-increasing prices, with occasional bumps on the way, as in the crisis of 1987. Jeremy Siegel's *Stocks for the Long Run* (McGraw-Hill, 2007) exemplified this notion of eternal and magical growth that engulfed investors big and small. Welcome to a world where every *microsecond* counts.

This book will provide readers with a comprehensive review of the evolution of high-frequency trading through the most important events that marked its growth from Nasdaq's founding in the early 1970s to the "flash crash" of May 6, 2010, seasoned with first-account insights from successful practitioners and experienced experts. Six practitioners, either founders, chief executive officers, presidents, or managing directors at their funds, have been interviewed in depth on a range of topics, including their educational background, their introduction to the financial world, their initial involvement with high-frequency trading, and how they are succeeding in today's financial markets.

Before we get into this fascinating world, let's start off with an overview of high-frequency trading, reviewing practitioners' thoughts on an appropriate definition of this practice, its emergence in the United States and the rest of the world, the ever-important technology question of build versus buy, how

profitable it really can be, the human component, and its impact on retail and institutional investors. Finally, we will walk through the definition of terms that sometimes get used incorrectly when describing high-frequency trading.

## Definition of High-Frequency Trading

*High-frequency trading* is a term that has grown to encompass a diverse number of strategies that share only a few traits. Asked for a definition, interviewees offered many different versions, and many more can be found in other literature on the topic.

That being said, there are some common themes among the various high-frequency trading strategies. Execution speed and therefore latency are important factors in high-frequency trading. Whereas seconds might have been considered high-frequency trading until not so long ago, now practitioners talk about milliseconds and microseconds as minimum speeds of execution for latency-sensitive strategies, speeds that typically can be experienced by those trading in Nasdaq OMX exchanges. Therefore, computers play an important role in replacing slow humans in the trading decisions.

Turnover is another important characteristic. Most practitioners turn their holdings over quite often as opposed to traditional fund managers; since the profits per transaction are small, the only way to compensate for their heavy investment in infrastructure is through the transaction of hundreds of thousands of shares. That is why exchanges battle to accommodate thousands of trades per second, because no high-frequency trader would like to face capacity constraints when dealing with an exchange.

Finally, practitioners are used to maintaining minimal or non-existent overnight positions. High-frequency traders are profitable when they are transacting, either through the small alpha of each transaction or potential rebates from the exchange; therefore, it doesn't make sense for them to maintain any holdings overnight;

as soon as they enter into a position, they try to profit from it and just as quickly get out. To be considered high frequency, what would the rate of turnover need to be? “Anything less than a day but typically more like a few minutes to a couple of hours,” says Manoj Narang, CEO of Tradeworx. “In practical terms,” he adds, “firms that run high-frequency strategies tend to finish the day with no stock holdings whatsoever.” Because this characteristic mathematically implies a rate of turnover of more than once per day and is much simpler and less arbitrary than focusing on a particular holding period, it is a perfectly good definition of a high-frequency strategy on its own. Thus Narang proposes this definition: A high-frequency strategy is a strategy that seeks to unwind all positions so that the trader can go home “flat” at the end of each trading day.

Ultimately, says Andrew Kumiega, director of quality at Infinium Capital Management, the goal of any high-frequency trading firm is to have a portfolio of uncorrelated trading strategies. “They can be built uncorrelated even by trading the same instrument over different time frames. So you can diversify your portfolio of algorithms by instrument, by market, by time frame, by algorithm, and hopefully if you have enough of those, obtain sufficient returns to cover your operating cost with very narrow risk distribution. Another option is working not only algorithms but also projects. Think about this: each new algorithm goes through developmental stages. You don’t know if your algorithm is going to work in stage 1; you really don’t know until you are at stage 2 ([or perhaps] stage 3) whether what you build will work. Thus you have a real option of building an algorithm. And the same diversification principle applies; you would want a bunch of algorithms in a pipeline.”<sup>1</sup>

Erik Lehtis, president of DynamicFX Consulting, explains the following defining characteristics of high-frequency trading: automation without any human intervention, employment of a

certain finite amount of capital, and profit maximization by turning over positions enough that one essentially could have as much exposure to market risk or value as one's capital would allow if one were just taking a position or holding it all day long. He says: "You are using systems to manage your risk, keep track of your positions, and calculate your P&L [Profit and Loss]. If you are doing all these things, you are, by definition, a high-frequency trader. It is not a matter of what your holding period is, if it is milliseconds or microseconds; there is no hard and fast definition. But you will be turning over your inventory several times, if not hundreds of times, every day."<sup>2</sup>

For Richard Flom, vice president of trading for Systematic Alpha Management, high-frequency trading is systematic, algorithmic, and data-intensive: "I think it is important to mention that [it] applies to the three types of high-frequency traders: people who make markets looking at the order book, high-frequency traders that trade in reversion, and high-frequency traders that look at trends. It does not matter how long your holding period is, but it matters what your strategy is, and that's as robustly as I can put it."<sup>3</sup>

Lastly, Andrew Kumiega thinks that there is no conclusive definition: "Ben Van Vliet, a colleague at the Illinois Institute of Technology, and I worked together for 10 years, writing papers and books on the topic; we have 30 consulting engagements together. We still could not define what high-frequency trading is. High-frequency trading means everything to everyone. To some people it's microseconds. Some people are executing stocks; some people are hedging."

## **The Emergence of High-Frequency Trading**

For many people, high-frequency trading is a recent phenomenon in the markets. By now, you must have noticed that the industry

didn't grow overnight but over the course of the last decade or so, with a dramatic increase in the volume of electronic trading in the last five years. While there were many developments prior to that, the starting point was around 2000, as soon as electronic mechanisms were invented to access exchanges, says Flom.

Flom thinks that we have just seen the beginning of electronic trading; it is indeed an evolution, and it's just coming around in the last few years. What algorithmic traders have done over the last few years is learn from their exchanges how to execute on them. High-frequency trading, says Flom, is not something that everyone just starting up can do.

"It is something that you can stumble upon and then becomes very difficult for you right away, and it is something that is a growing process," says Flom. "You have to learn how to do it, and it is not always profitable. In the last few years, there have been shops that have been successful at doing trading algorithmically, and there have been many shops that were not successful at all and went out of business. Moving forward, I think that we will see more automation in the market; people are realizing that there are more market strategies that you can apply algorithms to. So that is one of the trends that we see. Another trend is that more exchanges are becoming accessible via electronic means. And as more people get involved in trading, more and more exchanges will take place."

Lehtis remembers his beginnings in the industry: "I first got involved around 2003. There was already high-frequency trading as a process. At that time, you could get involved even if you were not perfect. You could have some success, learn from your mistakes, and get positive feedback through your returns. And you could fine-tune your algorithm and do all the work necessary to basically patch up your performance based on the outcomes that you had. I think now, coming into this space raw with a clean slate, attempting to build a high-frequency trading arbitrage strategy,

that it is a very challenging thing to do because you are not going to get the same kind of feedback. Even if you do 90 out of a 100 things right, you still will end up with negative returns because of the one thing that you didn't think of, and you are going to have a very hard time identifying it. So I don't envy anyone coming in now for the first time. I'm not saying it can't be done now, but it is a much more expensive proposition."

Looking forward, Lehtis says, "We will be dealing with much more perfect markets. Volatility and liquidity I think can have a very inverse relationship. The more you have of one, the less you have of the other. And right now we have a lot of volatility. But liquidity will return to the market and will give us some certainty as far as what we're doing. If the market feels at equilibrium, you won't be able to do these kinds of trades. Anything that is predictive, seeking alpha, I think those trades will be very interesting. Being able to model behavior on the fly, knowing where the market is going with some kind of certainty, that's where I'm most fascinated by the future of high-frequency trading. You want to be able to identify those moments where the market is about to turn, where that possibility is there, and be the first one to really start hitting the bid."

Paramount to the rapid evolution of high-frequency trading has been the fact that the United States has what is probably the world's most efficient equity market, says Petter Kolm, director of the mathematics in finance MS program at the Courant Institute of Mathematical Sciences of New York University. "That is for a number of different reasons. One is because of the great competition that we have in the intermarkets, and here I am not necessarily just talking about the participants, but I am also talking about the various trading venues that are competing. I mean, we have about 40 open equity trading venues in this country and, depending on how you count, probably about other 30 or so dark trading venues. And the major part of the liquidity provided in these

trading venues is from what we classically refer to as the market makers. However, we no longer see these guys running around on the floor, unless we look at some of the pits in Chicago. Instead, the market makers have been replaced by computer algorithms. That is technological innovation.”<sup>4</sup>

Even at this stage, Kolm admits that there is a certain level of fear among institutional investors and others, which happens with any new technology. “It takes a little bit of time to understand and absorb that,” he says. “We can see that time and time again; when we look at history, when the first cars came out, it was exactly the same kind of debacle in the media. I wasn’t around at that time, but I am sure it was pretty close to what we are seeing today. So I do think that one of the problems here is that there is a lack of information and a lack of education, and I can say that as an academic because that is what we are trying to change here. And over time, people will understand better what [high-frequency trading] is all about.”

## **Is There a Place for Outsourcing in High-Frequency Trading?**

In a recent poll released by Thomson Reuters of 100 New York-based representatives of hedge funds, proprietary traders, and broker-dealers, 50 percent of the participants stated that outsourcing parts of their high-frequency trading infrastructure would allow them to focus on higher-value-added activities and leverage their competitive advantages. Lehtis recommends that traders ask themselves what is it that they bring to the table that will make them successful in a way that other people are not and how are they going to compete with all the really smart people who are already in the space.

“There are a lot of people in this space already, regardless of what your assets are and what your time frames are,” says Lehtis.

“Any algorithm that you might think of, other people are running it as well. So what makes you so sure that you are going to be successful? That is the sort of thing that you want to spend your energy and resources on in-house. Anything else that has been done before, you can buy it. You will save yourself a lot of time and headaches by not trying to reinvent the wheel. There are so many moving parts in a high-frequency trading system, so many components involved. You can build them, but you could spend an entire lifetime building and never be satisfied with the result.” Traders might be looking for components to keep track of their risk, [but] those components have been developed so many times before [that it would be a waste of time for traders to develop those things themselves].” Lehtis says: “If that is the thing you think makes you special, then you are probably in the wrong business. Reduce everything to those trading components that you think are unique, and buy everything else. You’ll save yourself a ton of time and money actually, believe it or not.”

For Flom, the decision to outsource, difficult by nature, becomes more complex when traders realize they have to make a decision for each individual strategy. Traders will have to decide whether they want everyone to have access to it and have it outsourced, or whether they want it to be something that they keep in-house. Some of the easiest things to outsource are just the trading platforms that they are trading through, because those things are programmable and can be executed quite easily. It really takes a lot of development to come up with a proprietary trading platform, cautions Flom: “In the sense of gathering data and applying algorithms to it, you can outsource where you get your data from. But when you have the data and you want to apply the strategy to it, there is very little you can outsource because you have to have some secret or some knowledge about what you are doing to develop these strategies. So there are electronic procedures you can outsource, but in terms of your strategy, it is important to keep those things within the firm.”



## How Profitable Is High-Frequency Trading?

Throughout this book, the traders and I will be referring to an article that appeared in the print edition of the *New York Times* on July 24, 2009.<sup>5</sup> Several people attribute the popularity of high-frequency trading to the claims the article made. One of them was that high-frequency traders had generated \$21 billion in profits in 2008. This number was put into question by Manoj Narang and many other high-frequency traders, who argued that the number was totally out of range. In fact, Narang estimates that high-frequency trading in U.S. equities generates annual profits of \$2 billion to \$3 billion. With this mind, what can be said about the profitability of high-frequency trading?

John Netto, founder and president of M3 Capital, sees two ways to consider profitability in high-frequency trading: “There is profitability from a business development standpoint, whereas one develops a strategy that is extremely scalable and can manage a number of assets even if it doesn’t have the best returns. Then there is, of course, a strategy that can generate great returns but may face capacity constraints. At M3 Capital, we focus on developing both, because ultimately you want to be have a broadly diversified portfolio of noncorrelated quantitative strategies that takes into account a number of variables in the market.”

For Netto, in terms of high-frequency trading with a homogeneous sledge hammer or based on purely speed products, that market is largely, if not yet completely, dead. He thinks that there still might be some opportunities outside the United States for those who access the markets there. But in terms of triangular arbitrage strategies that involve multiple currency products or in terms of developing new models, he still sees a lot of opportunity.

In this regard, he thinks that the biggest threat in terms of what can make high-frequency trading difficult is volatility compression: “High-frequency trading, or at least algorithmic trad-

ing, is predicated on price recovery, and volatility compression makes price recovery a much greater hindrance. The opportunity to make markets, provide liquidity, at least from some of the strategies that we are talking about, is much greater. So the opportunities that exist, whether they are discerned algorithmically, via discretion, or via an approach that is somewhere between those two lines really plays on what the market environment is, what the microstructures are, and how you as an opportunist can attack those venues.”

There is a big issue with the more alpha-generating strategies at the ultra-high-frequency trading level, the market-making type of strategies. For Kolm, these are capacity constrained: “The hit rate is going to be a function of the number of people trading these strategies. So that is clearly capacity constrained, and that is the space we talk about. It is not about being fast; it is about being first, because, if you are faster than everyone else, you are the first one who can change your limit or the buys and sells at market moves, and you are also always going to be at the top of the book and have an opportunity to trade and make liquidity and thereby make the bid-ask rate and the associated rebate. So yes, there are capacity constraints, something we discussed during the turmoil in the markets of August 2007 and the quant turmoil, where people were trading fact-based strategies, and everyone realized that we were all trading exactly the same strategies here (at least on that particular day everyone was correlated). However, I don’t think it is something that we should have to worry so much about; we knew all that already when we got into that.”

Ultimately, concludes Peter van Kleef, CEO of Lakeview Arbitrage, the most profitable high-frequency trading strategies generally are the ones that are not well publicized and occur where people do things differently than the rest of the crowd.

## The Human Element in High-Frequency Trading

There are different opinions among my interviewees about human participation in the trading activities. Whereas some, such as Adam Afshar, suggest that humans should be completely removed from the trading process, others like to use the analogy of race cars or airplanes. Flom explains: “Race cars have been evolving over the last 10, 20, or 30 years, yet you still need someone behind the wheel. You can put an airplane on autopilot, but you still need someone behind the wheel to land it or take off. I think traders need to constantly be vigilant and to understand the risk and the algorithms they are trading. Traders can’t just look at a model and say that it isn’t working anymore; there is a constant pressure to be ahead of the game and understand what these algorithms are trading, to make sure that these algorithms are doing exactly what the researchers are expecting them to be doing, and giving them constant feedback, to the quants, researchers, and portfolio managers, about evolving strategies.”

Traders are the eyes, the people who are watching these markets and algorithms, contends Flom. The algorithms are very sophisticated, and these people need to be there. “I think we could all agree that if we locked up an algorithm and let it trade on its own for 10 minutes, we would find that a lot of things will go wrong,” he says. “Traders need to constantly monitor all the executions that are happening, give feedback, and provide all kinds of information back to research. Quants are sometimes just developing a model and putting it in trading; they never get to know how the model is doing. Sometimes there is nothing wrong with the model, even if it doesn’t work; sometimes it just needs to be tweaked. So they need to understand what these algorithms are, what they are trading, and why they are trading them and give continuous feedback as well as monitor all the risk that is involved in these systems.”

For Lehtis, traders have to be very involved in the technology because they have to be able to perform an autopsy on a

bad trade: “They have to be able to decide what’s wrong. The problem is that we usually only respond to positive feedback. But sometimes you are making money for the wrong reasons, and it certainly could cost you in the future.”

## **High-Frequency Trading in the United States and the World**

High-frequency trading started in the United States and continues to thrive here, according to James Leman, principal of Westwater Corp. He attributes this to the fact that the U.S. market is the optimal market right now for a lot of this type of trading. Ultimately, he adds, what matters is what traders are saying in terms of business opportunities, revenue opportunities, and the kinds of asset classes that traders are going after.

Despite the expansion of high-frequency trading around the world, the U.S. market is the one that gets talked about most in the trading community and also the one, with Europe, that is attracting more regulatory attention. As Leman says: “We need to pay attention to regulatory changes that are coming in the United States and probably should be in some level of motion in the European community. Naked access is the favorite poster child for what certain brokers allow certain high-frequency traders to do. There is a new rule in front of the Securities and Exchange Commission [SEC] that is being considered, talking about how brokers are going to have absolute responsibility for entitling buy-side customers to use their systems to get to the market; that would require documented procedures and the management of the company to sign off the annual review of how this takes place. The thought is that there is going to be essentially real-time risk controls imposed on high-frequency traders by brokers that give access to these electronic marketplaces, whether they are exchanges or ATs [Alternative Trading Systems].”

Important components of markets that allow high-frequency trading include small minimum price variations, small transaction sizes, and automatic execution. It all comes down to speed, though. According to Leman: “Ever since Regulation NMS went into effect, things also have become much more intense because you can’t get around it. High-frequency traders, because of the speed issue, are trying to get to the top of the book and hit the market as quickly as possible; that’s the name of the game, especially for the market-making guys as opposed to the risk-arbitrage-oriented people. So low latency is very important, and we obviously all know we have gone from milliseconds now into microseconds, so a number of people now are quantifying things in 100 microseconds or below. Exchanges are talking about it because they are competing with one another in terms of speed, broker-dealers are competing with one another in terms of speed, and third-party vendors are competing with one another in terms of speed, so speed is essential.”

The maker/taker pricing mechanism is important too; for market makers, the opportunity to earn the rebate along with the spread they pick up on doing the trading is the reason they are in the game; because of the transactions’ very minimal size, there’s a pressing need for high volumes of trading. Leman cites a recent statistic that looks at the number of orders versus the number of messages that go on; just one order to 30 messages that are going on canceling and replacing, canceling and replacing. That’s why ultrahigh speed is very important and we see the Singapore exchange reducing its time to execute trades from between 3 and 5 milliseconds to 90 microseconds, the fastest in the world.

Looking at the different elements that are necessary for high-frequency opportunities to really exist, the U.S. equities market has just about all of them. Says Leman: “U.S.-listed options, Canadian equities, and a number of European markets also have essentially all the components but maybe not some of

the speed issues, maybe not the maker/taker component, and maybe not some of the automatic execution mechanisms. Listed futures, foreign exchange, and other international markets are also developing.”

When Leman first got started in electronic trading, it seemed that the equity market in the United States was the poster child for how things were going to eventually follow out of the world. He was around at the New York Stock Exchange when it created the DOT [Designated Order Turnaround] system, and then the exchange started putting customer electronic trading on desks, first in the United States and later in Asia. Leman’s team helped to develop the Financial Information eXchange (FIX) Protocol,<sup>6</sup> still the de facto messaging standard for pretrade and trade communication globally within the equity markets. “So now we are seeing a number of MTFs [Multilateral Trading Facilities] evolving in Europe along with the way ECNs [Electronic Communication Networks] and ATs have evolved in the United States, and they are all now vying for things; we don’t have a consolidated type in Europe, but a number of people are trying to bring pressure to make that happen. We are seeing that every market is probably going through the same evolution in order to attract the same kind of trading activity. In most markets that developed outside the United States, the speed issue probably will continue to pick up in terms of adoption; in other words, the marketplaces will adopt these technologies more quickly than their predecessors did.”<sup>7</sup>

## **Money Managers and Institutional Investors as “Victims”?**

Much has been said about high-frequency trading and traditional money managers and institutional investors as “victims” of this activity. Practitioners interviewed for this book don’t see institutional investors in that way.

According to Kolm, institutional investors are already allocating capital to high-frequency trading strategies. “An important aspect of electronic trading for them is optimal execution. Executing large orders of shares is primarily a sell-side function being offered to institutional investors. I think this is a function that many of the large institutional investors want themselves to take charge of. That is the low-hanging fruit in electronic trading. And when people get comfortable with that, they look at what is the next branch, where is the next apple, and they will go a little bit higher up the tree. I think the institutional investors will get more and more comfortable with high-frequency strategies.”

Van Vliet envisions a new dynamic in this regard: “If you look at each strategy like a business, it is not inconceivable that someone could spin off their high-frequency market-making business to a larger institutional investor. Is this going toward a utility type of thing where there are a few very large institutional liquidity providers running market-making styles, high-frequency trading style strategies that require a tremendous amount of information technology infrastructure? If you look at it like a business that generates revenue, I think certainly you see institutional investors.”<sup>8</sup>

Lehtis agrees with Van Vliet’s proposed scenario: “A few dominant players try to take over, they discover what the economies of scale are, they just make it a critical-mass game that very few other people can play, and then they start merging with each other, and before you know, it is a monopoly. There is no doubt about it. The cost of entry in the high-frequency trading space is enormous, especially in foreign exchange, but I think in any of the asset classes. There is so much knowledge you need, so much technology you need to invest in, and it is the support of the technology as well as the initial build and the capital that you have to have available. It is a nontrivial tribute, and as time goes by and these firms get better, they will, without a doubt, just naturally push out the smaller players. So, if you want the benefits of self-

execution of these orders, and you are doing the smart writing yourself, rather than just receiving a price back from someone who did that for you, you have to be of a sufficient scale to make it economically worthwhile; otherwise, it just doesn't pay. So it is in the interest of the big firms to make that equation not work out to do it yourself but for you to execute orders through them."

While it is not surprising that most people haven't had the opportunity to learn about high-frequency trading in detail, it is surprising to see the range of opinions the practice elicits from traditional money managers, those who manage allocations from high-net-worth individuals to institutional investors.

Traditional value investors who follow the Graham-Dodd philosophy of investing don't seem to be bothered by high-frequency trading. Faithful to the investing discipline, they look for authentic value stocks that will perform positively over the long run; therefore, buying them at one or two more pennies wouldn't affect their performance. In fact, at one forum organized by Columbia Business School, alma mater of the greatest value investors, managers indicated that high-frequency trading had no impact whatsoever on their strategies.

## Important Definitions

Finally, there is so much information (or misinformation, according to some) about high-frequency trading that's important to know, that this Introduction would be incomplete if I neglected to define certain terms that will be discussed throughout this book.

- **Program trading** is a generic term used to describe a type of trading in securities, usually consisting of baskets of stocks. It is loosely defined as an electronic transaction involving 15 or more stocks with a combined value of at least \$1 million.



Three factors help to explain the explosion in program trading. First, technological advances spawned the growth of electronic communication networks (ECNs). These electronic exchanges, such as Instinet (later absorbed by Nasdaq OMX) and Archipelago (later absorbed by NYSE Euronext), allow thousands of buy and sell orders to be matched very rapidly without human intervention. Second, the SEC mandated in 2001 that the major stock exchanges price stocks in dollars and cents instead of fractions. A stock previously priced at  $7\frac{1}{8}$  is now listed at \$7.13. Pricing stocks in penny increments instead of  $\frac{1}{16}$  increments results in 100 price points within a dollar instead of the previous eight price points. This means that all the willing buyers and sellers are dispersed over many more prices, making it more difficult for them to meet on price. Finally, perhaps most significantly, the proliferation of hedge funds with all their sophisticated trading strategies is driving program-trading volume.<sup>9</sup>

- **Quantitative trading** refers to strategies based on quantitative analysis, which relies on mathematical computations and number crunching to identify trading opportunities. Price and volume are two of the more common data inputs used in quantitative analysis as the main inputs to mathematical models. Since quantitative trading generally is used by financial institutions and hedge funds, the transactions usually are large in size and may involve the purchase and sale of hundreds of thousands of shares and other securities. However, quantitative trading is also commonly used by individual investors.

Quantitative trading techniques include high-frequency trading, algorithmic trading, and statistical arbitrage. Many individual investors are more familiar with quantitative tools such as moving averages and oscillators.<sup>10</sup>

- **Algorithmic trading** is about using a set of rules to finesse trade execution. Algorithmic trading involves splitting a trade into multiple orders in order to reduce visibility and market impact, but the decision to take the main trade might or might not be automated. A fund manager might decide that a particular stock looks attractive based on his or her fundamental analysis and then instruct his or her trading desk to buy a block of stock. The traders on the desk might well use trade-execution algorithms to finesse the placement of this trade.<sup>11</sup>
- **Automated trading** involves a set of rules (a very simple example might be a pair of moving averages of different lengths crossing over) that, when satisfied, automatically trigger the placement of an order. A small, simple automated trade might be placed directly into the market, whereas a more substantial one might be handed to an execution algorithm for placement in small order slices so as to reduce market impact, etc. In brief, an automated model determines *whether* to place a trade, whereas an algorithmic model determines *how* to place it.<sup>12</sup>
- **Proprietary trading** refers to the practice by which banks, brokerages, and other financial institutions trade on their own account rather than on behalf of a customer. In simple terms, proprietary, or prop, trading is where a trading desk, using the bank's own capital and balance sheet, carries out trades in various instruments, often for speculative purposes. They can be ordinary shares and bonds traded on exchanges but more often are derivatives—either exchange-traded or in the over-the-counter markets—or foreign exchange. So-called pure proprietary trading is where traders trade for the bank's own profit, unrelated to client business. These traders generally are “walled off” from the rest of the bank and generate only a portion of total trading revenues. The practice is being severely limited in the United States by the Volcker rule, a

provision of the Dodd-Frank financial-overhaul law that was intended to curb the ability of banks to take risks with their own capital.

The other type of trading banks do is to help clients carry out trades, where the desk will use the bank's own capital to make a market in a certain instrument, offering itself as a buyer to a client who wants to sell or a seller to a client who wants to buy. Known as *flow business*, this is not speculative trading by the banks. Yet, to a certain extent, it still puts the bank's own capital at risk, sometimes in as significant a way as if the bank were conducting its own speculative prop trading.<sup>13</sup>

- **Statistical arbitrage**, or *StatArb*, as opposed to (deterministic) arbitrage, is related to the statistical mispricing of one or more assets based on the expected value of these assets. For example, consider a game in which one flips a coin and collects \$1 on heads or pays 50 cents on tails. In any single flip, it is uncertain if one will win or lose money. However, in the statistical sense, there is an expected value of  $\$1 \times 50\% - \$0.50 \times 50\% = \$0.25$  for each flip. According to the law of large numbers, the mean return on actual flips will approach this expected value as the number of flips increases. This is precisely the way in which a gambling casino makes a profit. In other words, statistical arbitrage conjectures statistical mispricings or price relationships that are true in expectation in the long run when repeating a trading strategy.

As a trading strategy, statistical arbitrage is a heavily quantitative and computational approach to equity trading. It describes a variety of automated trading systems that commonly make use of data mining, statistical methods, and artificial intelligence techniques. A popular strategy is pairs trading, in which stocks are put into pairs by fundamental- or market-based similarities. When one stock in a pair outperforms the other, the poorer performing stock is

bought long with the expectation that it will climb toward its outperforming partner; the other is sold short. This strategy hedges risk from whole-market movements.

In recent years, there has been a trend away from simple pair trading, and now it is more common for portfolios of stocks to be *clustered* by sector and region in offsetting any beta exposure. After the portfolio is constructed in this manner, it is usually optimized using risk models such as Barra/APT/EMA/Northfield to constrain or eliminate various risk factors.<sup>14</sup>

- **Ultra-high-frequency trading**, according to Telesis Capital's Rishi Narang, is a subcategory of high-frequency trading that is extremely sensitive to latency down to milliseconds and microseconds. "Most of the chatter out there now is really about ultra-high-frequency trading, when colocation really matters and shaving off milliseconds is important," he said. "It doesn't matter nearly as much for generic short-term quantitative trading."<sup>15</sup>