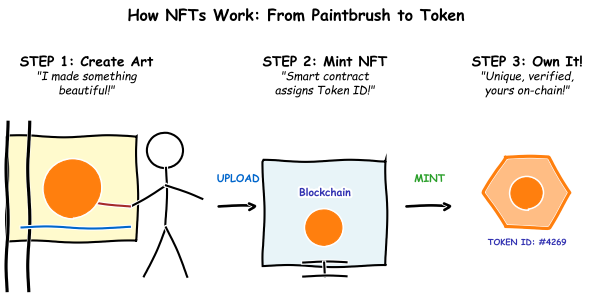
L08: NFTs & Token Standards – Technical Deep Dive

BSc Blockchain Course

Digital Finance

What If You Could Own a Digital Original – Not Just a Copy?



Every day you "buy" music, ebooks, and game skins – but you own none of them. You hold a revocable license controlled by a platform. NFTs flip this model: the token *is* the deed, recorded on a blockchain that no company can erase. Today we examine exactly how that works.

This cartoon frames the central question of Lesson 8: can blockchain turn digital files into ownable property?

Learning Objectives

By the end of this lesson you will be able to:

1. **Define** fungible, non-fungible, and semi-fungible token standards (ERC-20, ERC-721, ERC-1155). *[Understand]*
2. **Explain** how NFT metadata is stored and the trade-offs between on-chain, IPFS, and centralized storage. *[Understand]*
3. **Calculate** creator royalty payments across multiple resales using EIP-2981. *[Apply]*
4. **Compare** NFT marketplace models on fee structure, royalty enforcement, and decentralization. *[Analyze]*
5. **Evaluate** whether a proposed NFT use case delivers genuine utility beyond speculative value. *[Evaluate]*

Bloom's levels covered: Understand, Apply, Analyze, Evaluate

These objectives map directly to quiz and exercise assessments.

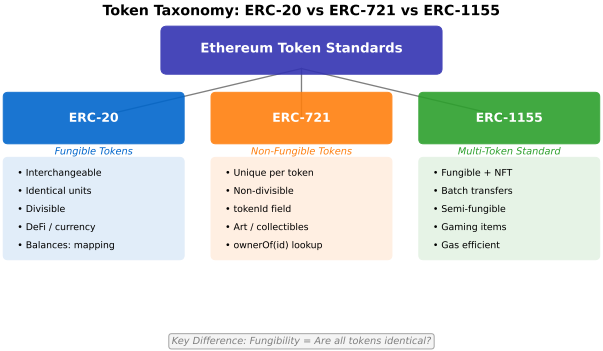
Token Standards: The Language of Digital Ownership

In Lesson 7 we saw how DeFi uses smart contracts to move money without banks. Today we ask a different question: what if smart contracts could represent **ownership** itself?

Ethereum token standards define a shared language so that any wallet, marketplace, or application can recognise and transfer digital assets:

- **ERC-20** = money (fungible, every unit identical)
- **ERC-721** = deed (non-fungible, every token unique)
- **ERC-1155** = both in one contract (fungible + non-fungible)

Why standards matter: Without a shared interface, every NFT project would need its own marketplace, its own wallet integration, and its own transfer logic. Standards make composability possible.



- **What you see:** A taxonomy tree showing how token standards branch from a common root.
- **Key pattern:** ERC-20 handles quantity; ERC-721 handles identity; ERC-1155 unifies both.
- **Takeaway:** Choosing the right standard is the first design decision in any token project.

Think About Something You Own Digitally – Do You Really Own It?

Take a moment and think about the digital goods you have paid for:

Consider these scenarios:

- You bought a song on a streaming platform. Can you **resell** it?
- You purchased an ebook. Can you **lend** it to a friend permanently?
- You earned a rare skin in a video game. If the game shuts down, does the skin **still exist**?
- You have 10,000 photos in a cloud account. What happens if the company **closes your account**?

In every case, you hold a **revocable license**, not ownership. The platform can change terms, remove content, or shut down – and your "purchase" vanishes.

NFTs propose an alternative: a token on a blockchain that proves you own a specific digital asset. No platform can revoke it, no company can delete it. But this model brings its own risks – we will examine both sides today.

Apple's iTunes Store terms: "You agree that Apple may change, suspend, or discontinue access to purchased content at any time."

What Is an NFT? A Definition Built on Uniqueness

Definition: Non-Fungible Token (NFT)

An **NFT** is a cryptographic token on a blockchain that represents a **unique** digital or physical asset. Unlike fungible tokens (where every unit is interchangeable), each NFT has a distinct identity and cannot be swapped one-for-one with another.

Four defining properties:

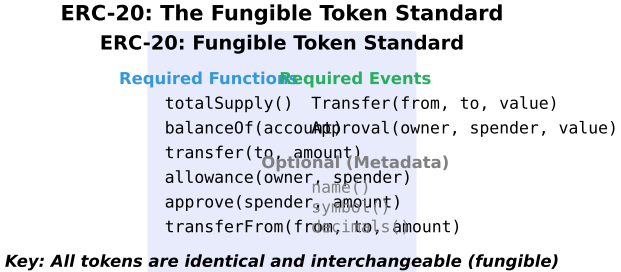
1. **Unique tokenId:** Every NFT within a contract is identified by a unique integer. Token #42 is not the same as token #43.
2. **Owner mapping:** The smart contract stores exactly one owner address per tokenId. Ownership is publicly verifiable on-chain.
3. **Metadata URI:** Each token points to a metadata file (JSON) that describes the asset – name, description, image URL, attributes.
4. **Transferable:** The owner can send the token to any other address, just like sending cryptocurrency – no platform permission needed.

Analogy: Think of an NFT as a *digital deed of ownership*. The deed itself is on the blockchain; the house (the media file) may be stored elsewhere.

The ERC-721 standard was finalized in January 2018 (EIP-721). CryptoKitties (Dec 2017) was the first viral NFT application.

ERC-20: The Fungible Token Interface

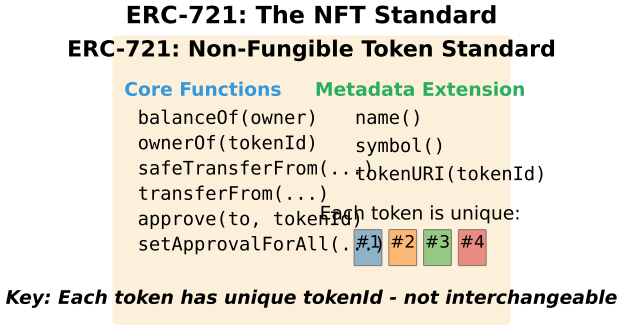
- **Six required functions:** `totalSupply`, `balanceOf`, `transfer`, `allowance`, `approve`, `transferFrom`
- **Two required events:** `Transfer` and `Approval` – every token movement is logged on-chain
- **Optional metadata:** `name()`, `symbol()`, `decimals()` are recommended but not mandatory
- **Fungibility rule:** Every unit is identical – token #1 equals token #2. This is what makes ERC-20 suitable for currencies and governance votes, not for unique assets.



ERC-20 (EIP-20) was finalized in November 2015. It is the standard behind USDC, DAI, UNI, and thousands of other tokens.

ERC-721: The NFT Interface Explained

- **Core functions** include `ownerOf(tokenId)` – a single call proves who owns a specific token with no ambiguity
- **Safe transfer:** `safeTransferFrom` checks the recipient can handle NFTs, preventing tokens from being locked in contracts forever
- **Metadata extension:** `tokenURI(tokenId)` returns the JSON URL that describes the asset – name, image, attributes
- **Non-interchangeability:** Token #1 is not the same as token #2. Each has a distinct identity tracked by `tokenId`.



ERC-721 was finalized in January 2018. CryptoKitties (Dec 2017) stress-tested an early version and congested the Ethereum network.

ERC-1155: One Contract, Many Token Types

- **Unified contract:** A single ERC-1155 deployment can manage both fungible tokens (health potions $\times 100$) and unique NFTs (legendary sword #1) simultaneously
- **Batch transfers:** Send 10 different token types in a single transaction – one gas payment instead of ten
- **Gas savings:** Batch minting 100 items costs $\sim$97% less than 100 separate ERC-721 transactions
- **Gaming use case:** Designed by the Enjin team specifically for game economies mixing consumables and rare items

ERC-1155: Best of Both Worlds

ERC-1155: Multi-Token Standard

Single Contract, Multiple Types:

Fungible: x100

Non-Fungible: #1 #2 #3

Key Features:

* Batch transfers
* Mixed fungible/NFT
* Gas efficient
* Single contract

Ideal for: Gaming items (swords x100, unique legendaries)

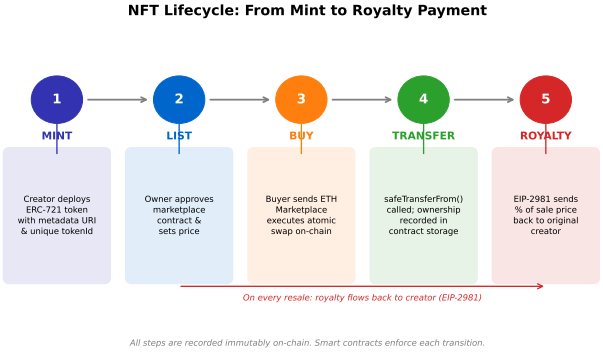
ERC-1155 was finalized in June 2019. The Enjin team built it after observing that gaming studios needed both fungible and non-fungible tokens.

The NFT Lifecycle: From Minting to Resale

An NFT goes through a predictable lifecycle from creation to repeated resale. Understanding each stage reveals where value and risk concentrate.

Five stages:

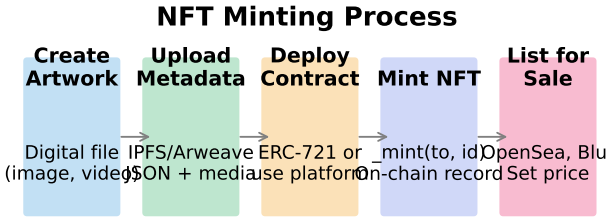
1. **Mint:** The creator deploys a smart contract and calls a function that assigns a new tokenId to their address.
2. **List:** The owner approves a marketplace contract to transfer the token on their behalf, then sets a price.
3. **Buy:** A buyer sends payment; the marketplace contract atomically swaps the NFT for the payment.
4. **Transfer:** Ownership updates on-chain. The buyer is now the verified owner.
5. **Royalty:** If the creator set a royalty rate (EIP-2981), a percentage of each resale is routed back to them.



- **What you see:** A flow diagram showing the five stages from mint to royalty payment.
- **Key pattern:** Every resale triggers a royalty payment – the creator earns in perpetuity.
- **Takeaway:** The lifecycle is enforced by smart contract code, not by marketplace policy.

The NFT Minting Process: From File to On-Chain Record

- **Step 1 – Create artwork:** Prepare the digital file (image, video, audio) that the NFT will represent
- **Step 2 – Upload metadata:** Store the JSON file and media on IPFS or Arweave before minting; the URI is embedded in the token
- **Step 3 – Deploy contract:** Use an existing platform (OpenSea, Manifold) or deploy a custom ERC-721 contract
- **Step 4 – Mint:** Call `_mint(to, tokenId)` to create the on-chain record; gas cost: 0.001–0.01 ETH per token
- **Lazy minting:** Defer on-chain minting until first purchase – the buyer pays gas, reducing creator upfront cost to zero



Costs:
Gas for deployment: 0.01-0.1 ETH
Gas per mint: 0.001-0.01 ETH
Lazy minting: buyer pays gas

Platform minting (OpenSea, Rarible) abstracts contract deployment. Custom contracts give creators full control over royalties and metadata.

ERC-20 vs ERC-721 vs ERC-1155: Feature Comparison

Three token standards dominate Ethereum. Each serves a different purpose. Choosing the wrong standard wastes gas, limits functionality, or both.

Dimension	ERC-20	ERC-721	ERC-1155
Uniqueness	Fungible (identical)	Non-fungible (unique)	Both in one contract
Batch transfer	No (one tx per transfer)	No (one tx per token)	Yes (many tokens, one tx)
Gas efficiency	Low per-token cost	High per-token cost	Lowest per-token cost
Divisibility	Yes (18 decimals)	No (whole tokens only)	Configurable
Metadata	Optional (name, symbol)	Required (tokenURI)	Required (uri)
Primary use case	Currencies, governance	Art, collectibles, deeds	Gaming items, mixed assets

Key insight: ERC-1155 was designed by the Enjin team specifically for gaming, where a player might own 100 identical health potions (fungible) and one legendary sword (non-fungible) – all managed by one contract.

Rule of thumb: If every token is identical, use ERC-20. If every token is unique, use ERC-721. If you need both, use ERC-1155.

ERC-1155 was finalized in June 2019 (EIP-1155). It reduces deployment costs by up to 90% compared to separate ERC-20 + ERC-721 contracts.

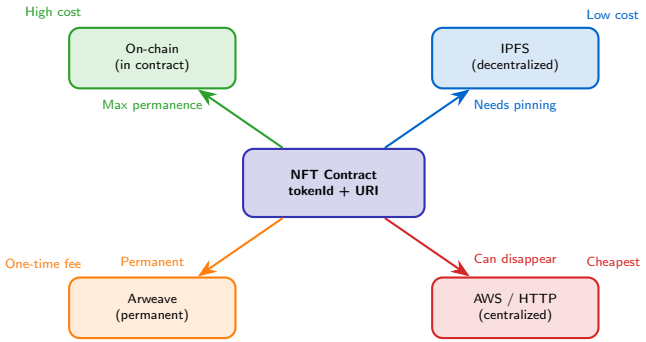
Where Does the Image Live? Metadata Architecture

An NFT on the blockchain stores only a **tokenId** and a **URI** (a web address pointing to metadata). The actual image, video, or audio lives *off-chain*. Where that metadata is stored determines how permanent and decentralized the NFT truly is.

Four storage options:

1. **On-chain:** Data stored directly in the smart contract. Permanent, but extremely expensive ($1,000+ per image).
2. **IPFS:** Content-addressed decentralized storage. Permanent *if* someone keeps pinning the file.
3. **Arweave:** One-time payment for permanent storage. "Pay once, store forever" model.
4. **Centralized (AWS/HTTP):** Cheapest and fastest, but the server owner can delete or change the file at any time.

Trade-offs: cost vs permanence vs decentralization. Most NFT projects use IPFS as a compromise.



A 2023 study found that 40% of NFTs from 2021 pointed to metadata on centralized servers – many links were already dead.

Inside NFT Metadata: The JSON That Describes Your Token

- **Name and description:** Human-readable fields displayed in every marketplace and wallet interface
- **Image field:** Points to the media file – typically an IPFS URI (`ipfs://Qm...`) for decentralized storage
- **Attributes array:** Trait-type/value pairs that define rarity – background colour, accessory, special property
- **tokenURI chain:** `tokenURI(id)` → metadata URL → JSON file → image URL. Each link in this chain can break.
- **Storage choice matters:** IPFS and Arweave are preferred; centralized HTTP links are a red flag for permanence

NFT Metadata Structure

NFT Metadata JSON

```
{
  "name": "CryptoPunk #1234",
  "description": "A unique punk",
  "image": "ipfs://Qm...",
  "external_url": "https://..",
  "attributes": [
    {"trait_type": "Background",
     "value": "Blue"},
    {"trait_type": "Rarity",
     "value": "Legendary"}
  ]
}
```

Storage Options

IPFS Decentralized, content-addressed

Arweave Permanent, pay once

On-chain Most secure, expensive

Centralized Risky, avoid

tokenURI(id) -> returns metadata URL -> JSON -> image URL

The OpenSea metadata standard is the de facto format. Attributes drive rarity rankings on tools like Rarity Sniper and Trait Sniper.

Royalty Payments: A Worked Example

Problem: An artist mints an NFT with a 5% royalty (EIP-2981). How much does the artist earn across the primary sale and two resales?

Setup: Primary sale $10,000; Resale 1 $25,000; Resale 2 $15,000.

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$\$10{,}000 + \$1{,}250 + \$750 =$ **\$12,000**

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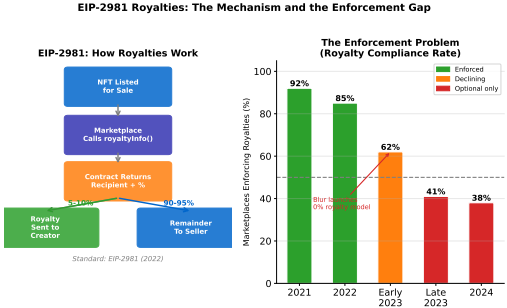


Royalty enforcement rates vary by marketplace. EIP-2981 signals the rate; honouring it is voluntary.

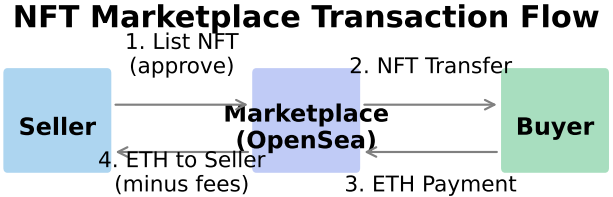
EIP-2981 defines a standard royalty interface, but enforcement depends on the marketplace honouring the on-chain signal.

How Royalty Splits Work: Seller, Creator, Marketplace

- **Three-way split:** On a 1 ETH secondary sale with 7.5% royalty and 2.5% platform fee – seller receives 0.90 ETH, creator 0.075 ETH, marketplace 0.025 ETH
- **EIP-2981 interface:** `royaltyInfo(tokenId, salePrice)` returns the receiver address and royalty amount – one call returns both values atomically
- **Voluntary enforcement:** The standard signals the rate; marketplaces choose whether to honour it. Blur made royalties optional in 2022, triggering industry debate.
- **Creator benefit:** Even a 5% royalty compounds over many resales – a work that trades 10 times at rising prices can generate multiples of the primary sale revenue

Some projects embed royalty enforcement in the contract itself by blocking transfers to non-compliant marketplaces – a controversial but effective approach.

How NFT Marketplaces Connect Buyers and Sellers



Fee Structure (typical):

Marketplace: 2.5%

Creator Royalty: 2.5-10%

Gas: variable

Royalties: Creator earns on every resale

Three listing models:

1. **Fixed price:** Seller sets a take-it-or-leave-it price. First buyer to pay gets the NFT. Simple and predictable.
2. **English auction:** Bids increase over time. Highest bidder wins when the timer expires. Maximizes seller revenue for popular items.
3. **Dutch auction:** Price starts high and drops at intervals until someone buys. Used for large collections to find market-clearing price.

Gas Cost Comparison: Minting on Different Chains

Problem: How much does it cost to mint a single NFT on Ethereum, Polygon, and Solana? Gas prices change constantly, but the relative magnitudes are instructive.

Assumptions:

- Minting an ERC-721 token requires approximately 80,000 gas units
- Ethereum gas price: 30 gwei (1 gwei $= 0.000000001$ ETH), ETH $= \$2{,}000$
- Polygon gas price: 30 gwei on MATIC, MATIC $= \$0.50$
- Solana: flat fee of approximately 0.00001 SOL, SOL $= \$150$

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Chain	Gas Cost (native)	USD Equivalent	Relative Cost
Ethereum	$80{,}000 \times 30$ gwei $= 0.0024$ ETH	$4.80	1x (baseline)
Polygon	$80{,}000 \times 30$ gwei $= 0.0024$ MATIC	$0.0012	0.00025x
Solana	0.00001 SOL	$0.0015	0.0003x

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Takeaway: Ethereum minting costs roughly **3,000–4,000 times more** than Polygon or Solana. This explains why many NFT collections launch on Layer-2 networks or alternative chains. The trade-off: Ethereum offers the strongest security and largest buyer pool.

Gas prices fluctuate dramatically. During high demand, Ethereum gas can spike above 200 gwei, pushing mint cost above $30.

Marketplace Showdown: OpenSea vs Blur vs Rarible

The NFT marketplace landscape shifted dramatically in 2023–2024. Three platforms illustrate different competitive strategies:

OpenSea (est. 2017):

- 2.5% platform fee
- Enforced creator royalties until 2023; made optional under pressure
- Largest selection, most user-friendly interface

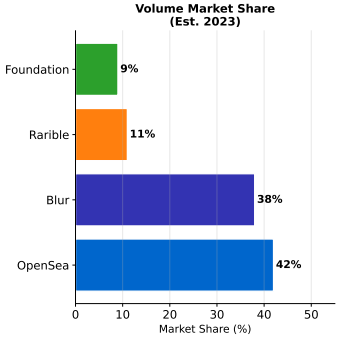
Blur (est. 2022):

- 0% platform fee; optional creator royalties
- Pro-trader tools: batch buying, portfolio analytics
- Surpassed OpenSea in volume within 6 months

Rarible (est. 2020):

- Community-governed (RARI token)
- Multi-chain support (Ethereum, Polygon, Tezos)
- Smaller volume, stronger creator focus

NFT Marketplace Comparison: OpenSea vs Blur vs Rarible vs Foundation



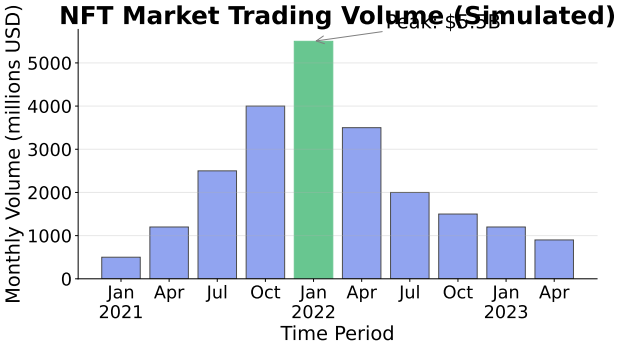
Feature Comparison

Platform	Maker Fee	Taker Fee	Royalties Enforced?	Focus	Token?
OpenSea	0%	2.5%	Optional	General	No
Blur	0%	0.5%	Optional	Pro/High-v	BLUR
Rarible	1%	1%	Yes	Creator	RARI
Foundation	5% royalty	0%	Yes	Fine Art	No

- **What you see:** Volume and fee comparison across the three major marketplaces.
- **Key pattern:** Lower fees attract volume, but at the cost of creator royalty enforcement.
- **Takeaway:** The "race to zero fees" benefits traders but undermines

NFT Trading Volume: The Boom-Bust Cycle in Numbers

- **2021 explosion:** Monthly trading volume climbed from $500M in January to a peak of $5.5B – driven by celebrity endorsements, BAYC launches, and speculative fever
- **2022 crash:** Volume fell 60–80% from peak as rising interest rates drained risk appetite across all speculative assets
- **2023 floor:** Volume stabilized around $900M/month – still 10× higher than pre-boom 2020 levels
- **Structural shift:** High-volume months correlate with marketplace token incentive programs, not just organic demand – making raw volume figures unreliable as demand signals

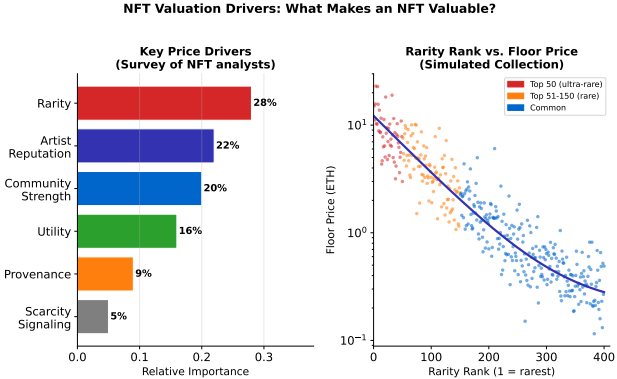


Data: simulated to reflect published DappRadar and Nansen market reports. Real data shows similar boom-bust pattern across all major chains.

What Drives NFT Prices? The Valuation Puzzle

Unlike stocks or bonds, NFTs have no cash flows, no earnings, and no standard valuation model. Price discovery relies on subjective factors:

- **Rarity:** Traits that appear in fewer than 1% of a collection command significant premiums. Rarity tools rank every token.
- **Utility:** Does the NFT grant access to events, governance votes, or in-game abilities? Utility creates recurring demand.
- **Community:** Strong communities (Bored Ape Yacht Club, CryptoPunks) sustain floor prices through identity and status.
- **Artist reputation:** Beeple's "Everydays" sold for $69 million because of 13 years of daily art output.
- **Cultural significance:** First-mover projects (CryptoPunks, Autoglyphs) hold value as historical artifacts.



- **What you see:** A breakdown of factors that influence NFT prices, weighted by market evidence.
- **Key pattern:** Rarity and community drive short-term price; utility determines long-term survival.
- **Takeaway:** Projects that rely solely on speculation collapse when

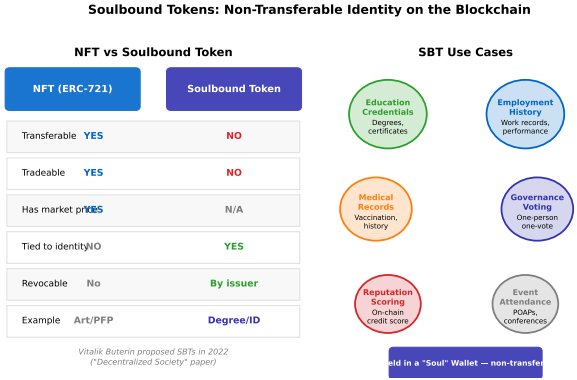
Soulbound Tokens: NFTs You Cannot Sell

Not all ownership should be transferable. A university degree, a driver's license, or a professional certification represents *your* achievement – selling it to someone else defeats its purpose.

Soulbound Tokens (SBTs) are non-transferable NFTs proposed by Vitalik Buterin in 2022. Once issued to your wallet (your "soul"), they cannot be sent to anyone else.

Use cases:

- **Academic credentials:** Degrees and certificates verifiable on-chain without contacting the university
- **Professional reputation:** Proof of contributions to open-source projects or DAOs
- **Identity verification:** KYC attestations that prove you passed a check without revealing personal data
- **Voting rights:** Governance tokens tied to participation history, not wealth



- **What you see:** Soulbound token use cases mapped across identity, credentials, and reputation.
- **Key pattern:** SBTs invert the NFT model – value comes from non-transferability, not tradability.
- **Takeaway:** SBTs could make blockchain useful for identity systems.

Batch Minting: ERC-1155 Gas Savings

Problem: A game studio wants to mint 100 unique in-game items for a new release. How much gas does ERC-721 require compared to ERC-1155?

Assumptions:

- ERC-721 minting cost: approximately 80,000 gas per token
- ERC-1155 batch minting cost: approximately 200,000 gas total (one transaction)
- Gas price: 30 gwei; ETH = $2,000

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- Gas price: 30 gwei; ETH = \$2,000

ERC-721 approach (100 separate transactions):

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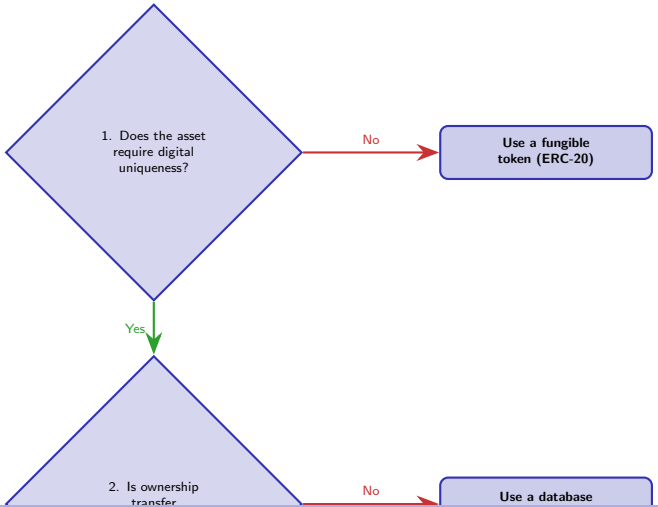
Takeaway: ERC-1155 batch minting saves the studio $468 on just 100 items. For a collection of 10,000 items, the savings would be roughly $47,000 – enough to fund an entire development sprint.

Batch operations are one reason gaming projects overwhelmingly choose ERC-1155 over ERC-721.

When to Use an NFT: A Decision Framework

Not every digital asset needs to be an NFT. Before tokenizing, walk through this decision tree. If any answer is "no," a simpler solution (database, API, traditional DRM) may be sufficient.



Wash Trading: When the Volume Is a Lie

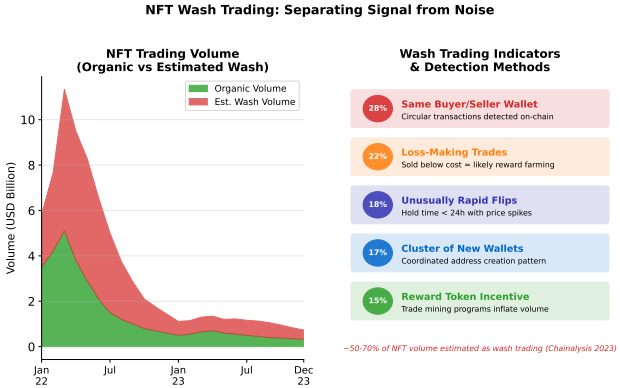
Wash trading occurs when a trader buys and sells to themselves (using different wallets they control) to artificially inflate volume and create the illusion of market demand.

Why it happens in NFTs:

- **Token incentives:** Blur and other platforms reward high-volume traders with token airdrops – wash trading generates "free" tokens.
- **Price manipulation:** Inflated sale history tricks buyers into overpaying for artificially "blue-chip" collections.
- **Pseudonymous wallets:** Anyone can create unlimited wallets, making self-dealing easy to execute.

Detection methods:

- Wallet clustering (same funding source)
- Circular transaction patterns
- Selling at a loss repeatedly (irrational without incentives)



- **What you see:** Estimated wash trading volume as a percentage of total NFT trading volume.
- **Key pattern:** Wash trading spiked in 2022–2023 during marketplace "wars" with token incentives.
- **Takeaway:** Always question volume figures. High volume does not

The Metadata Problem: When Your NFT Points to a Dead Link

The most underappreciated risk in NFTs is not price volatility – it is **metadata fragility**. If the image file disappears, you own a token that points to nothing.

Three failure modes:

1. **Server shutdown:** The project hosted images on AWS or a personal server. When the team disbanded, the server went offline. Your NFT now displays a broken-image icon.
2. **Rug pull via metadata swap:** The contract owner calls `setBaseURI()` and changes all images from art to blank files – or worse, to offensive content. The tokens remain, but the art is gone.
3. **IPFS unpinning:** Files on IPFS persist only while at least one node "pins" (actively stores) them. If no one pins your NFT's metadata, the content becomes unretrievable.

Mitigation strategies:

- Use **Arweave** for permanent storage (one-time payment model)
- Use **IPFS with Filecoin** pinning contracts (decentralized pinning)
- **Freeze metadata:** Lock the tokenURI so the contract owner cannot change it after minting
- **On-chain metadata:** Store critical attributes directly in the smart contract (expensive but indestructible)

Before buying an NFT, check where metadata is stored. Run the tokenURI through a gateway – if it returns an HTTP URL, proceed with caution.

Legal Uncertainty, Copyright, and Consumer Protection

NFTs exist in a legal grey zone. Three categories of risk affect creators, buyers, and platforms differently.

Risk Category	Description	Who Is Affected	Current Status
Copyright	Buying an NFT does *not* transfer copyright. You own the token, not the intellectual property.	Buyers who assume they own the underlying IP	No global standard; some projects grant commercial rights (e.g., BAYC)
Securities law	NFTs sold with profit expectations may qualify as securities under the Howey test.	Creators, platforms, investors	SEC has not issued clear NFT-specific guidance; case-by-case enforcement
Consumer protection	No refund mechanism; irreversible transactions; no buyer recourse on fraud.	Retail buyers unfamiliar with crypto risks	EU MiCA may classify certain NFTs as financial instruments

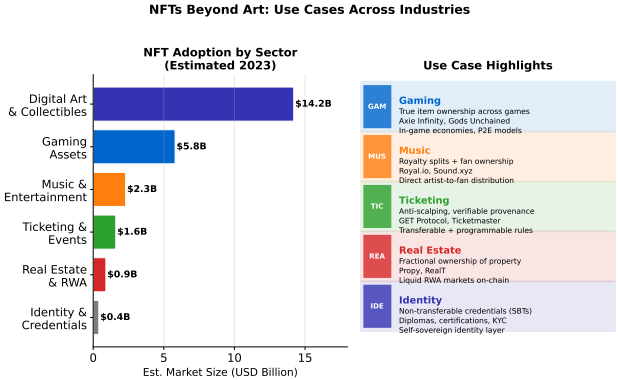
Key insight: The legal status of NFTs varies by jurisdiction and changes frequently. Always verify: (1) what rights the NFT grants, (2) whether the project's terms of service are enforceable, and (3) what recourse exists if the project fails.

The Howey test (1946): an "investment contract" exists when money is invested in a common enterprise with profit expectations from others' efforts.

NFTs Beyond Art: Real-World Applications

The 2021 hype cycle focused on profile pictures and generative art, but the lasting impact of NFTs may come from non-speculative applications:

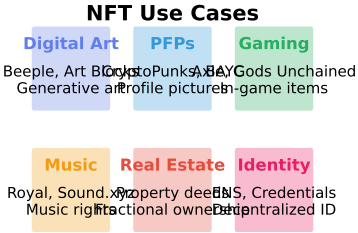
- **Gaming:** In-game items that players truly own and can trade across platforms (Axie Infinity, Gods Unchained)
- **Music:** Artists sell limited-edition tracks directly to fans, retaining 95%+ of revenue (Sound.xyz, Audius)
- **Real estate:** Fractional ownership of property via tokenized deeds (Propy, RealT)
- **Identity:** Verifiable credentials that you control, not a corporation (ENS domains, Worldcoin)
- **Event tickets:** Unforgeable tickets with built-in resale royalties that eliminate scalping fraud (GET Protocol)



- **What you see:** NFT use cases by sector, showing adoption beyond the art market.
- **Key pattern:** Utility-driven applications (gaming, tickets, identity) are growing while speculative art declines.
- **Takeaway:** The most durable NFT applications solve a real ownership

A Map of NFT Applications: Six Sectors, One Technology

- **Digital art & PFPs:** The 2021 boom category – Beeple, Art Blocks, CryptoPunks, BAYC. High speculation, high volatility.
- **Gaming:** Axie Infinity and Gods Unchained proved players will pay for truly ownable in-game items that survive server shutdowns
- **Music rights:** Royal and Sound.xyz let fans buy royalty fractions – a direct artist-to-listener economic relationship
- **Real estate:** Propy and RealT tokenize property deeds, enabling fractional ownership and 24/7 settlement
- **Identity:** ENS domains and verifiable credentials replace platform-controlled usernames with self-sovereign identifiers



NFTs enable provable ownership and scarcity for any digital asset

NFT provable ownership and scarcity apply to any digital asset. The technology is domain-agnostic; the value depends on the use case.

The NFT Market: Boom, Bust, and What Survived

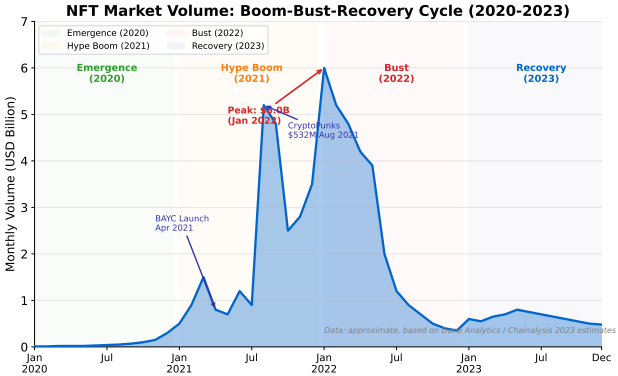
The NFT market follows a pattern familiar from other technology bubbles: explosive hype, painful correction, then quiet maturation.

Timeline:

- **2020:** Niche market ($100M annual volume)
- **2021 Q1–Q3:** Explosion (Beeple's $69M sale, BAYC launch). Monthly volume peaked at $5B+.
- **2022:** Crash alongside broader crypto downturn. Average NFT prices fell 90%+.
- **2023–2024:** Market "floor." Projects with real utility or strong communities survived; pure-speculation projects died.

What survived the crash:

- CryptoPunks, BAYC (cultural status)
- ENS domains (utility: human-readable addresses)
- Gaming NFTs (functional in-game value)



- **What you see:** NFT trading volume over time, showing the boom-bust cycle.
- **Key pattern:** The trough volume (2024) is still 10x higher than pre-boom levels (2020).
- **Takeaway:** The speculative bubble popped, but the underlying

Token Distribution Across the Ecosystem

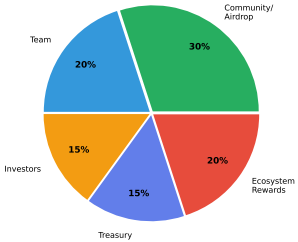
How are tokens distributed within the NFT and broader crypto ecosystem? Understanding distribution reveals concentration risks and market dynamics.

Key distribution patterns:

- **Whale concentration:** In most top collections, fewer than 5% of wallets hold more than 50% of tokens
- **Long-tail creators:** Millions of NFTs minted by individual artists generate less than 1% of total volume
- **Platform dominance:** The top 3 marketplaces handle over 90% of secondary trading volume
- **Chain concentration:** Ethereum hosts approximately 80% of NFT value despite cheaper alternatives existing

Why this matters: Concentrated ownership means a few large holders can manipulate floor prices by listing or delisting strategically.

Typical Token Distribution (ERC-20)



Note: Team/Investor tokens typically have vesting periods (1-4 years)

- **What you see:** Distribution of token holdings across wallet segments.
- **Key pattern:** A power-law distribution – a small number of wallets hold most of the value.
- **Takeaway:** "Decentralized" ownership does not mean "evenly distributed" ownership.

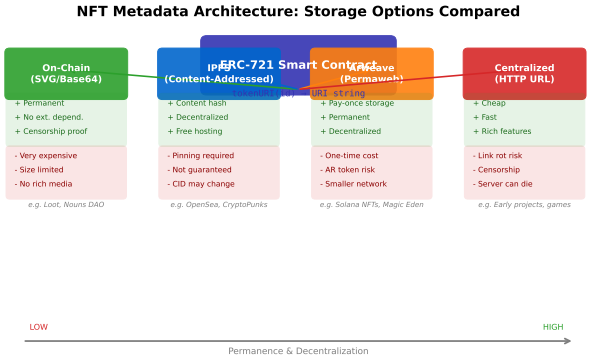
Nansen analytics: in the top 100 NFT collections, the top 10% of holders control 70%+ of total floor value.

Who Wins When Ownership Becomes Programmable?

Programmable ownership means the rules of who owns what, and under what conditions, are encoded in software. This reshapes stakeholder dynamics:

Stakeholder	Impact
Artists/Creators	+ Perpetual royalties
Gamers	+ True item ownership
Collectors	+ Verifiable provenance
Authenticators	+ Unforgeable certificates
Speculators	+/− High volatility
Counterfeiters	− On-chain audit trail
Platforms	− Reduced lock-in

The permanence question: If metadata disappears, programmable ownership loses its anchor. This is why metadata architecture (frame 9) is not a technical detail – it is the foundation of the entire value proposition.



- **What you see:** Metadata storage architecture showing how on-chain tokens link to off-chain content.
- **Key pattern:** The weakest link in the metadata chain determines the NFT's true permanence.
- **Takeaway:** Programmable ownership is only as durable as the metadata layer that supports it.

The Creator Economy Revolution

NFTs fundamentally change the economic relationship between creators, platforms, and fans. Compare the traditional model with the NFT model:

Dimension	Traditional Model	NFT Model
Revenue split	Platform takes 30–70%	Creator keeps 85–95%
Secondary sales	Creator gets $0	Creator gets 2.5–10% royalty
Fan relationship	Platform-mediated	Direct (wallet-to-wallet)
Content control	Platform can remove/demonetize	Creator retains on-chain record
Portability	Locked to one platform	Token moves across marketplaces
Discovery	Algorithm-dependent	Community-driven

The promise: A musician on Spotify earns $0.003–$0.005 per stream. Selling 1,000 NFT editions at $10 each yields $10,000 immediately, plus royalties on every resale.

The caveat: Discovery remains the hard problem. Without a platform's algorithm, reaching an audience requires an existing fanbase or community. NFTs change the economics of creation but do not solve the distribution problem.

Daniel Allan raised $50,000 in 2022 by selling 1,000 music NFTs on Sound.xyz – bypassing labels and distributors entirely.

Five Questions to Evaluate Any NFT Project

Use this evaluation framework before buying, building, or investing in any NFT project. Projects that score well on all five questions have the strongest chance of long-term survival.

The Five Questions:

1. **Metadata permanence:** Where is the metadata stored? On-chain, IPFS with pinning, or a centralized server that could disappear?
2. **Genuine utility:** Does the NFT do something beyond being a collectible? Does it grant access, functionality, or governance rights?
3. **Team transparency:** Is the team public and accountable? Have they shipped before? Anonymous teams with large treasuries are red flags.
4. **Royalty enforcement:** Does the marketplace honour creator royalties, or can buyers bypass them? If royalties are optional, the creator economy argument weakens.
5. **Community health:** Is the community engaged in the project's mission, or purely focused on floor-price speculation?

Scoring: 5/5 = strong project fundamentals. 3–4/5 = investigate further. Below 3 = high risk of failure or fraud.

This framework is not financial advice. It is a structured way to separate signal from noise in a noisy market.

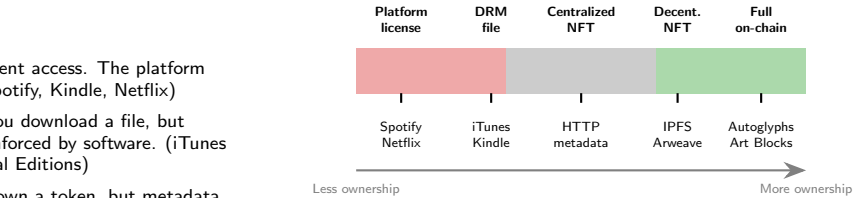
The Ownership Spectrum: From License to True Ownership

Digital ownership exists on a spectrum. Understanding where different systems sit helps evaluate whether an NFT adds genuine value.

Moving left to right:

- **Platform license:** You rent access. The platform controls everything. (Spotify, Kindle, Netflix)
- **DRM-protected file:** You download a file, but usage restrictions are enforced by software. (iTunes purchases, Adobe Digital Editions)
- **Centralized NFT:** You own a token, but metadata lives on a centralized server. Ownership is fragile.
- **Decentralized NFT:** Token on-chain, metadata on IPFS/Arweave. Ownership is durable.
- **Full on-chain:** Everything – token, metadata, and media – stored on the blockchain. Maximum permanence, maximum cost.

Most NFTs today sit in the middle. True on-chain ownership remains rare due to storage costs.



Key insight: "I own an NFT" can mean very different things depending on where the project sits on this spectrum. Always ask: *what exactly would survive if every company involved shut down tomorrow?*

Autoglyphs (2019) was one of the first fully on-chain generative art projects – the art is generated by and stored in the smart contract itself.

What Comes Next: Layer 2 Scaling

Today you learned *what* NFTs are, *how* token standards work, and *when* tokenization makes sense. In Lesson 9, we zoom into the infrastructure that makes NFTs affordable at scale: Layer-2 networks.

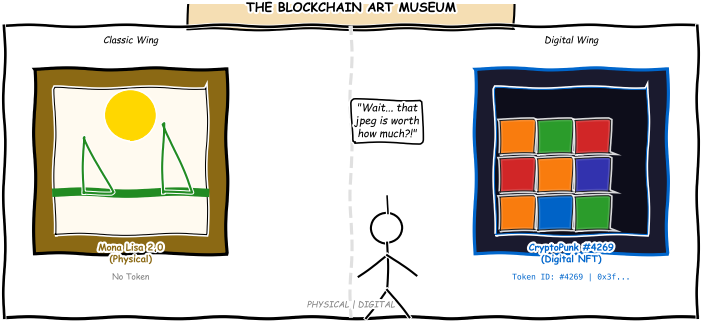
Lesson 9 will cover:

- **Rollups (Optimistic and ZK):** How transactions are bundled off-chain and verified on Ethereum, cutting gas costs by 10–100x while inheriting Ethereum's security
- **State channels:** Direct payment channels between two parties that settle on-chain only when the channel closes – instant finality for repeated interactions
- **Sidechains vs rollups:** Why Polygon PoS (sidechain) and Polygon zkEVM (rollup) have different security models despite sharing a brand name
- **The modular blockchain thesis:** Separating execution, data availability, and consensus into specialized layers – how this design could finally solve the scalability trilemma

Preparation: Review the gas cost comparison from frame 12. Layer-2 solutions are the answer to the question: "How do we get Ethereum's security at Solana's price?"

Lesson 9 builds directly on today's gas cost analysis and the scalability constraints discussed throughout this lecture.

One Last Thought...



Now you understand that "owning an NFT" ranges from holding a pointer to a dead link all the way to possessing an indestructible on-chain record. The technology is powerful – but only when the metadata layer is as robust as the token itself.

The best NFT projects start with an ownership problem, not with a speculative opportunity.

Key Takeaways

1. **Token standards defined:** ERC-20 (fungible), ERC-721 (non-fungible), and ERC-1155 (multi-token) provide the shared language that makes digital ownership interoperable across wallets and marketplaces.
2. **Metadata is the weak link:** The token lives on-chain permanently, but the image or media it points to may not. Storage choice (on-chain, IPFS, Arweave, centralized) determines true permanence.
3. **Creator royalties change economics:** EIP-2981 enables artists to earn from every resale, but enforcement depends on marketplace cooperation – it is not guaranteed.
4. **Gas costs shape design:** ERC-1155 batch minting saves 97%+ in gas versus ERC-721. Chain selection (Ethereum vs L2 vs alt-chain) changes costs by orders of magnitude.
5. **Speculation vs utility:** The 2021 bubble proved that hype alone is not sustainable. Projects with genuine utility (gaming, tickets, identity) survived; pure-speculation projects collapsed.
6. **Evaluate before investing:** Metadata permanence, utility, team transparency, royalty enforcement, and community health are the five dimensions that separate strong projects from fragile ones.

Review question: Given a new NFT project, walk through the five-question evaluation framework from frame 26 and rate it.

Summary / Next Lesson Preview

NFTs transform digital files from copyable data into ownable assets by recording unique tokenIds on a blockchain. Three standards (ERC-20, ERC-721, ERC-1155) define how fungible and non-fungible tokens are created, transferred, and queried. The technology enables perpetual creator royalties, verifiable provenance, and cross-platform interoperability – but only when the metadata layer is as permanent as the token itself. The market's boom-bust cycle showed that speculation alone does not sustain value; utility, community, and technical robustness do.

Key Vocabulary:

- Non-Fungible Token (NFT)
- ERC-721 / ERC-1155
- Metadata URI / tokenURI
- IPFS (InterPlanetary File System)
- EIP-2981 (Royalty Standard)
- Soulbound Token (SBT)
- Wash trading
- Floor price
- Lazy minting
- On-chain vs off-chain storage

Next lesson: *Layer-2 Scaling Solutions* – how rollups, state channels, and sidechains make blockchain transactions fast and cheap without sacrificing security.

Try this before Lesson 9: look up any NFT on OpenSea, click "Details," and check where the metadata is stored. Is it IPFS, Arweave, or HTTP?