

# NFTs & Digital Assets: Ownership in a Copy-Paste World

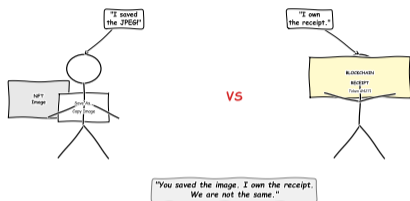
## Three Threads of the Tokenization Revolution

Prof. Dr. Jörg Osterrieder

BSc Blockchain, Crypto Economy & NFTs

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## [Cartoon] You Saved the Image. I Own the Receipt.



Someone right-clicks your NFT and saves it.

"Got it!" they say. "Free art."

You check the blockchain. You still own it. They own a JPEG. You own the receipt — the only copy that Ethereum recognizes.

They have the pixels. You have the provenance.

**But what exactly do you own?**

Not the copyright. Not the pixels. Not even the file. You own a number in a ledger that points to a URL that points to an image that anyone can copy.

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This lecture explores what digital ownership actually means — and when it is worth paying for.

**By the end of this lecture, you will be able to:**

1. **Explain** how ERC-721 and ERC-1155 create provable digital scarcity and how tokenURI links on-chain tokens to off-chain metadata
2. **Describe** how IPFS (InterPlanetary File System) content addressing and Arweave permanent storage solve the metadata permanence problem
3. **Apply** a valuation framework to distinguish sustainable NFT value from speculative hype
4. **Compare** NFT marketplace mechanisms and analyze why royalties collapsed
5. **Evaluate** whether a proposed RWA (Real-World Asset) tokenization project addresses legal, custody, and regulatory requirements

*Prerequisites: Basic blockchain concepts (Blockchain Foundations lecture).*

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These objectives span Bloom levels from Understand to Evaluate.

# Why Does Digital Ownership Need Reinventing?

## The copy problem revisited:

Digital files can be copied infinitely at zero cost. A copy is identical to the original.

Before NFTs, digital ownership required a central authority — Steam, Apple, Spotify — to track who “owns” what.

That authority can revoke access, delist content, or shut down entirely.

*You never owned your digital purchases. You rented access.*

## NFTs change the default:

A token on a public blockchain = ownership without a gatekeeper.

The token persists even if the marketplace closes.

No company can revoke it. No server shutdown deletes it.

But ownership of *what*, exactly?

Owning an NFT is not the same as owning the copyright. It is closer to owning a signed certificate of authenticity.

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Digital ownership before NFTs always required trusting a company. NFTs replaced the company with a contract.

## A Thought Experiment

Open your Steam library. Your Kindle collection. Your Spotify playlists.

How much have you spent? Do you *own* any of it?

In 2009, Amazon remotely deleted George Orwell's *1984* from customers' Kindles — after they paid for it. In 2023, Ubisoft shut down servers for older games, making purchased titles unplayable.

Your digital library exists at the pleasure of a corporation.

**What if your digital purchases lived on a ledger no company could alter?**

*Think about the last digital purchase you made. What happens to it if the platform closes tomorrow?*

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**Every digital purchase you have ever made is a permission, not a possession — unless it lives on a blockchain.**

## Definition

A **Non-Fungible Token** (NFT) is a unique identifier stored on a blockchain that points to metadata describing a specific asset.

### Three essential properties:

1. **Unique:** Each token has a distinct ID — no two are identical within a contract
2. **Verifiable:** Ownership history is publicly auditable on the blockchain
3. **Transferable:** The owner can sell, gift, or burn the token without permission from any authority

### Key distinction:

*Fungible* = interchangeable. Your 1 ETH is identical to my 1 ETH.

*Non-fungible* = unique. Your CryptoPunk #7523  $\neq$  any other CryptoPunk.

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**Non-fungible = not interchangeable. Every dollar is the same; every NFT is different.**

# What Does an NFT Actually Contain?

## On-chain (permanent):

- Token ID (unique number)
- Owner address (current holder)
- Token URI (pointer to metadata)
- Transfer history (every sale/gift)
- Smart contract address

*These persist as long as Ethereum exists.*

## Off-chain (depends on storage):

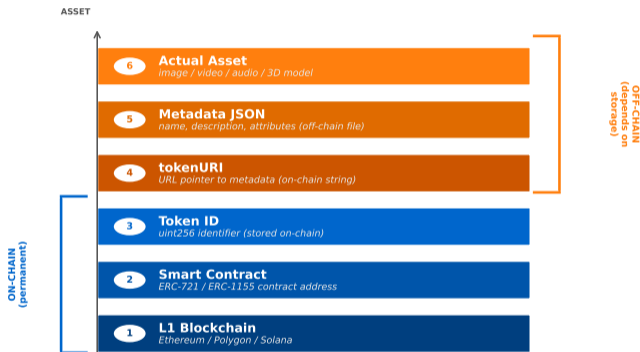
- Metadata JSON (name, description)
- Image or media file
- Traits and properties
- Animation or interactive content

The blockchain stores the receipt. The art lives elsewhere. If "elsewhere" goes offline, you own a receipt pointing to nothing.

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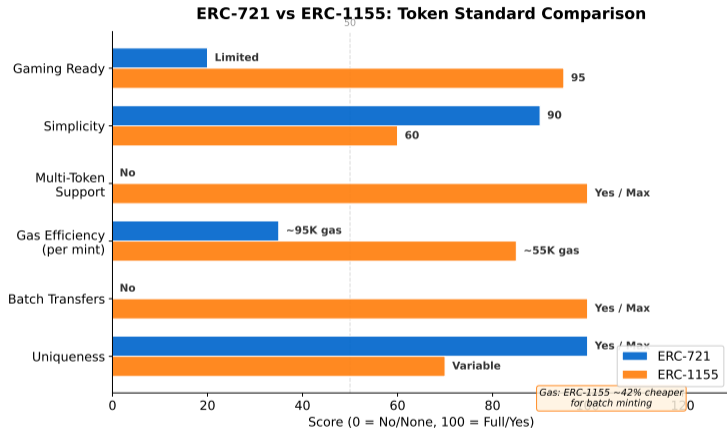
**The most common misconception: the image is NOT on the blockchain. Only the pointer is.**

## The Six Layers of an NFT



- **What you see:** Six layers from blockchain base to visible artwork
- **Key pattern:** Ownership lives on layers 1–3 (permanent); the actual asset lives on layers 5–6 (fragile unless stored properly)
- **Takeaway:** An NFT is only as permanent as its weakest layer

Layers 1–3 are immutable. Layers 4–6 are only as permanent as the storage provider.



- **What you see:** Two standards compared across six dimensions
- **Key pattern:** ERC-721 = every token completely unique; ERC-1155 = both unique and semi-fungible in one contract
- **Takeaway:** ERC-1155 is more gas-efficient for collections and games; ERC-721 is simpler for one-of-a-kind art

ERC-721 launched CryptoPunks and Bored Apes. ERC-1155 powers most blockchain games.

## The record:

- March 11, 2021 — Christie's auction house
- Final price: \$69.3 million
- Third-most expensive living artist sale
- Buyer: Metakovan (Vignesh Sundaresan)
- Artwork: collage of 5,000 daily digital images created since May 2007

*The most expensive digital artwork ever sold.*

## What the buyer actually got:

- An ERC-721 token on Ethereum
- An image file on IPFS (pinning-dependent)
- **No** copyright transfer
- **No** physical object
- **No** exclusive viewing rights

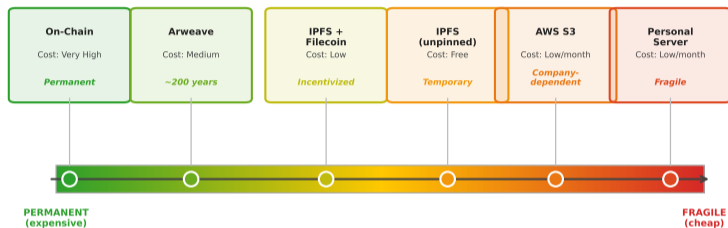
Anyone can view, download, and print the image. Only Metakovan owns the token.

*He paid for provenance, not pixels.*

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**The buyer paid \$69M for a blockchain receipt + an IPFS hash. The art is free to view. The provenance is not.**

## NFT Metadata Storage: Permanence vs Cost



Most NFT images are NOT stored on-chain — they depend on a URL that can go offline.

- **What you see:** A spectrum from fully on-chain storage to centralized servers
- **Key pattern:** Most 2021–2022 NFTs used centralized servers or unpinned IPFS — the cheapest, least permanent options
- **Takeaway:** Permanent ownership requires permanent storage; most early NFTs failed this test

In 2022, a study found 40% of NFT metadata links were already broken.

# CryptoPunks to BAYC: What Makes a Collection Valuable?

## **The first wave (2017–2020):**

CryptoPunks — 10,000 pixel-art characters.

Given away free in 2017. Floor price peaked above 80 ETH in 2022.

**Value driver:** historical provenance. “The first NFT collection on Ethereum.”

No roadmap. No utility. No commercial rights. Pure collectible status.

## **The PFP era (2021–2022):**

Bored Ape Yacht Club — 10,000 apes.

Mint price: 0.08 ETH. Peak floor: 150+ ETH. Current floor: ~15 ETH.

**Value driver:** community + commercial rights.

### **Worked example:**

Peak: 150 ETH × \$3,500 = \$525,000

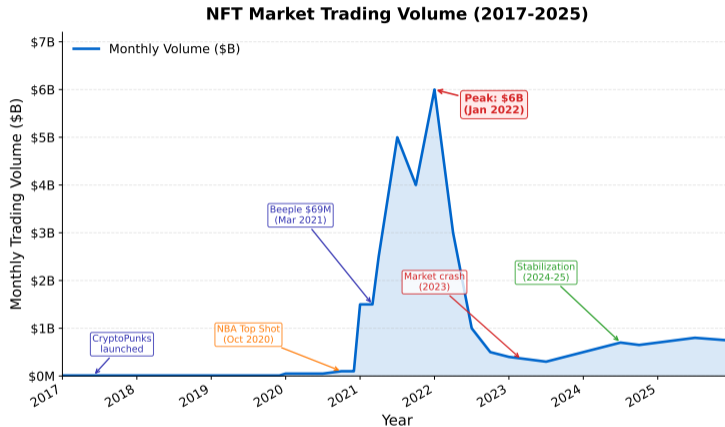
Now: 15 ETH × \$2,500 = \$37,500

**Loss: 93%**

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CryptoPunks derived value from historical provenance. BAYC from community and commercial rights. Both crashed.

# The NFT Market: Boom, Bust, and What Survived



- **What you see:** NFT trading volume from 2017 to 2025 with annotated milestones
- **Key pattern:** Volume exploded 100x in 2021, crashed 90% by 2023, and stabilized at a lower but non-zero baseline
- **Takeaway:** The speculative bubble burst, but the technology survived; usage shifted from art to utility and RWA

Most NFT analyses confuse speculation (the bubble) with adoption (the technology).

# How Do NFT Marketplaces Actually Work?

## Listing and matching:

1. Seller lists NFT (signs off-chain order)
2. Buyer places bid or accepts price
3. Smart contract holds escrow
4. Atomic swap: NFT and payment exchange simultaneously

The Seaport protocol (OpenSea, 2022) made marketplace mechanics open-source — anyone can build a marketplace.

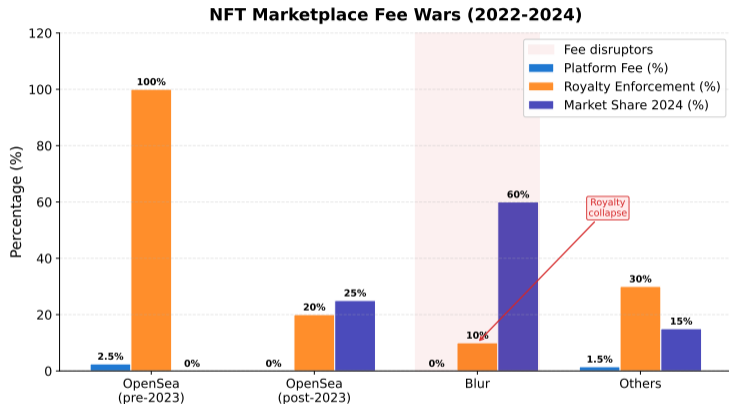
## Three auction types:

1. **English auction:** price goes up, highest bidder wins (Christie's model)
2. **Dutch auction:** starts high, drops over time, first buyer wins
3. **Fixed price:** take it or leave it

Dutch auctions prevent gas wars — instead of 10,000 people racing to mint at the same second, the price drops until demand matches supply.

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The Seaport protocol made marketplace mechanics open-source — anyone can fork a marketplace.



Royalty Enforcement: 100% = always enforced, 20% = optional, 10% = rarely enforced

- **What you see:** Market share shifting from OpenSea to Blur as fees dropped to zero
- **Key pattern:** When Blur launched with zero fees and optional royalties (Oct 2022), OpenSea's dominance collapsed within months
- **Takeaway:** In a commoditized market, the platform that charges least wins — at the expense of creators

OpenSea charged 2.5% + enforced royalties. Blur charged 0%. Blur won.

## Worked Example: Why Did Creator Royalties Collapse?

### The promise:

ERC-2981 proposed a standard: creators earn a percentage (typically 5%) on every resale. Passive income forever.

### How it worked:

Artist sells NFT for 1 ETH.

Buyer resells for 10 ETH.

Artist receives 0.5 ETH (5%).

*A revolutionary idea: creators earn from secondary markets.*

### The reality:

Royalties are **not enforced at the protocol level**. They are a marketplace convention.

- Nov 2022: Blur launches with optional royalties
- Feb 2023: OpenSea matches — drops mandatory royalties
- Royalty revenue collapses industry-wide

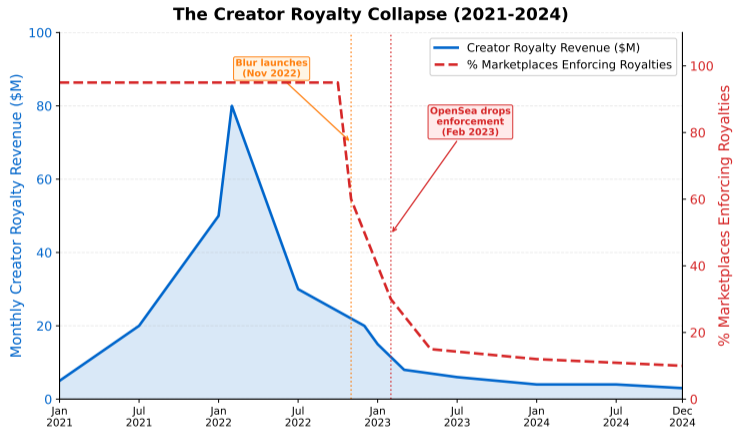
### Worked example:

Creator earning \$50K/month → \$2K/month

**Decline: 96% in 90 days**

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Royalties were a gentleman's agreement. When competition arrived, the agreement broke.



- **What you see:** Creator royalty revenue dropping sharply after marketplace fee competition began
- **Key pattern:** Voluntary royalties held when one marketplace dominated; they collapsed when competition rewarded defection
- **Takeaway:** Standards without protocol-level enforcement are fragile — game theory predicts defection when stakes are high

The royalty collapse is a case study in cryptoeconomics: voluntary standards fail when competition rewards defection.

## The Axie Infinity experiment:

- 2.7 million daily active players (Nov 2021)
- Players in the Philippines earned \$300–\$1,500/month
- In-game token SLP peaked at \$0.39
- NFT creatures (Axies) traded for thousands of dollars

*For many players, Axie Infinity was a full-time job.*

## The collapse:

- SLP price: \$0.39 → \$0.003 (**99.2% decline**)
- Daily players: 2.7M → 400K
- Ronin bridge hack: \$625M stolen (March 2022)
- Average Axie value: \$300 → \$2

**Root cause:** new player purchases funded existing player rewards. When growth slowed, the token economy collapsed.

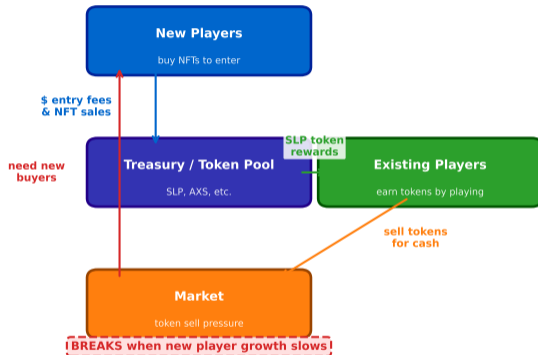
*A game that requires perpetual growth is not a game — it is a pyramid.*

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**Axie Infinity was the largest P2E experiment. Its collapse revealed P2E's dependency on perpetual growth.**

## Play-to-Earn Token Flow: The Growth Dependency

Example: Axie Infinity (peak 2021 → collapse 2022)



- **What you see:** Sustainability factors compared across P2E models — most rely on new entrants to fund rewards
- **Key pattern:** Games with external revenue sources (cosmetics, subscriptions) survive; pure token-reward models collapse
- **Takeaway:** The test: would people play if the token had zero value? If no, it is speculation, not gaming

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## Technical risks:

- Metadata loss (server goes offline)
- Smart contract bugs (no patches possible)
- Marketplace centralization (platform risk)
- Wash trading (fake volume inflates prices)

*Technical risks are assessable — check storage, read the contract, verify volume.*

## Economic risks:

- Liquidity collapse (no buyers at any price)
- Royalty non-enforcement (creator income vanishes)
- Regulatory reclassification (Howey test: investment with expected profit from others' efforts)
- Rug pulls (team abandons project)

## Risk Heuristic

Anonymous team + vague roadmap + high mint price = walk away. All three together have a near-perfect track record of failure.

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**The most dangerous NFT risk is not technical — it is assuming digital scarcity equals value.**

## What is RWA tokenization?

Converting physical or financial assets into tokens on a blockchain.

### Asset types:

- Treasury bonds and money market funds
- Real estate (fractional ownership)
- Commodities (gold, carbon credits)
- Private credit and invoices

Smart contracts automate compliance, dividends, and transfers.

## Why institutions care:

- BlackRock BUIDL fund (March 2024): ~\$500M in tokenized Treasuries
- JP Morgan Onyx: \$1B+ daily repo transactions
- 24/7 settlement (vs T+2 in traditional finance)
- Fractional access: invest \$100 in a \$10M building

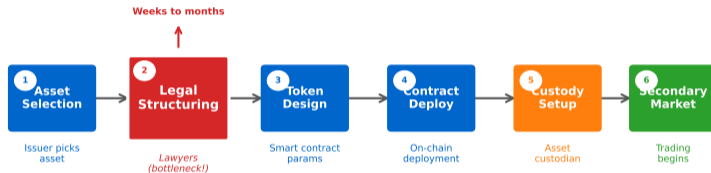
*The same blockchain that traded ape JPEGs now settles institutional bonds.*

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RWA tokenization is growing faster than NFT art ever did — and with institutional capital behind it.

## RWA Tokenization: The 6-Step Pipeline

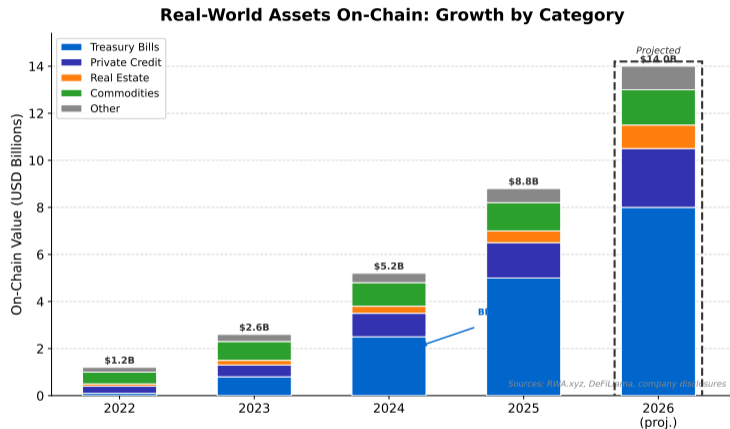
*From real-world asset to on-chain token — legal structuring is the critical path*



- **What you see:** A multi-step workflow from real-world asset to tradeable on-chain token
- **Key pattern:** Legal structuring (step 2) and custody arrangement (step 3) take longer than all technical steps combined
- **Takeaway:** Tokenization is 20% technology and 80% legal engineering

**Step 2 (legal structuring) takes longer than steps 3–6 combined. The blockchain is the easy part.**

# The RWA Market: What is Already On-Chain?



- **What you see:** RWA tokenization growing from near-zero to billions in total value locked, led by Treasuries and private credit
- **Key pattern:** Simple, fungible, legally clear assets (Treasuries) tokenized first; complex assets (real estate) lag behind
- **Takeaway:** The market is following the path of least regulatory resistance

**BlackRock BUIDL alone holds more value than most NFT collections ever reached.**

# Who Benefits and Who Gets Hurt?

## Winners:

- **Digital creators** (with caveats) — direct sales, global audience, no gallery fees
- **Fractional investors** — access assets previously limited to the wealthy
- **Institutions** — 24/7 settlement, reduced counterparty risk
- **Emerging market users** — property rights via blockchain where legal systems are weak

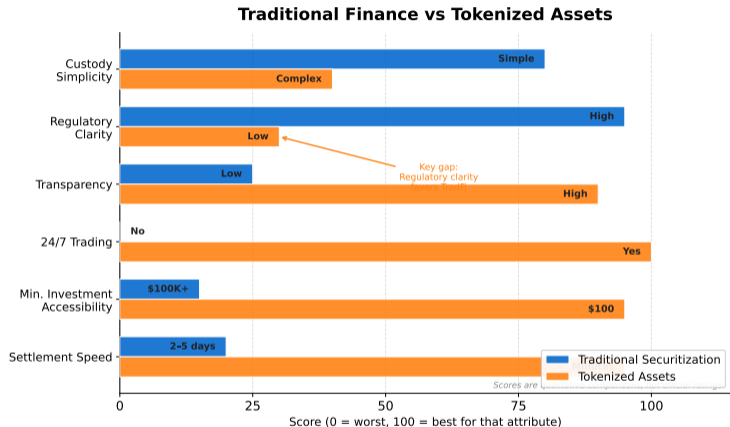
*The NFT market rewarded early participants and punished latecomers — a pattern common to all speculative assets.*

## Losers:

- **Speculative NFT buyers** — 90%+ losses on most collections
- **Creators dependent on royalties** — revenue collapsed with fee wars
- **P2E gamers** — token rewards became worthless
- **Unregulated project holders** — no recourse when teams disappear

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The NFT market rewarded early participants and punished latecomers — regardless of the underlying technology.



- **What you see:** Tokenized and traditional finance compared on settlement speed, access, cost, and transparency
- **Key pattern:** Tokenization wins on speed and fractional access; traditional finance wins on legal clarity and investor protection
- **Takeaway:** The future is hybrid — tokenized rails with traditional legal wrappers

Tokenization advantages are clearest in cross-border transactions where T+2 settlement costs billions annually.

## What we learned:

**Thread 1 — Ownership:** The on-chain record is permanent, but the pointer to the asset may not be. Storage determines durability.

**Thread 2 — Value:** Digital scarcity enables new markets but does not guarantee value. Speculation and utility are different things.

**Thread 3 — Tokenization:** The technology moved from art speculation to institutional finance in under four years.

## The convergence:

Technology creates infrastructure for ownership. But value requires *human* systems: law, culture, utility.

- NFT art proved the concept
- Gaming revealed the limits
- RWA may deliver the promise

*The question was never “can we put things on a blockchain?” It was always “should we — and for which things?”*

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**NFTs were never about JPEGs. They were always about the infrastructure for digital ownership.**

# Five Questions to Evaluate Any NFT or Tokenized Asset

**Before buying, minting, or investing — ask:**

1. **Where is the metadata stored?** On-chain, IPFS with pinning, Arweave, or a company server?
2. **What do you legally own?** A token? A license? Copyright? A share of revenue?
3. **Who controls the smart contract?** Is there an admin key? A multisig (multi-signature wallet)? Is it renounced?
4. **What creates demand beyond speculation?** Utility, access, yield, cultural significance?
5. **What happens if the platform closes?** Does the token survive independently?

## Decision Heuristic

$$\text{NFT Value} = (\text{Permanence of Storage} \times \text{Legal Clarity} \times \text{Demand Driver}) / \text{Speculation Premium}$$

If any numerator term is zero, the value proposition collapses regardless of the others.

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**Apply these five questions to the next NFT or tokenized asset you encounter.**

## [Cartoon] The Token Points to Nothing

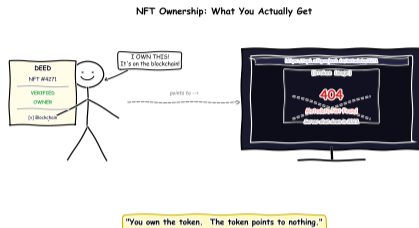
We started with a question: *what do you actually own when you own an NFT?*

The answer has three parts:

1. **A permanent record** — the token on the blockchain. Immutable.
2. **A permanent asset** — only if stored on IPFS with pinning or Arweave. Most are not.
3. **A legal framework** — only if the jurisdiction recognizes token-based ownership. Most do not yet.

True digital ownership requires all three. Most NFTs have only the first.

*From right-click-save jokes to tokenized Treasuries: the journey from skepticism to institutional adoption took just four years.*



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From right-click-save to tokenized Treasuries: the journey from skepticism to institutional adoption.

## Five ideas to remember from today:

1. **Ownership infrastructure:** ERC-721 and ERC-1155 create provable scarcity, but the asset is only as permanent as its storage layer
2. **Metadata matters:** IPFS with pinning or Arweave for permanence; a centralized URL is a ticking clock
3. **Speculation vs utility:** The 2021 bubble proved technology works; the 2023 crash proved hype is not value
4. **Marketplace dynamics:** Voluntary royalties collapse under competition — protocol-level enforcement or nothing
5. **RWA is the next frontier:** Tokenized Treasuries and real estate are growing faster than NFT art ever did

## Decision Heuristic:

$$\text{NFT Value} = (\text{Permanence of Storage} \times \text{Legal Clarity} \times \text{Demand Driver}) / \text{Speculation Premium}$$

*If you cannot answer all five evaluation questions, you are speculating, not investing.*

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**These five takeaways map directly to the three threads introduced at the start.**

## Today's three threads:

- **Thread 1:** Ownership — on-chain records are permanent, but pointers and assets may not be
- **Thread 2:** Value — scarcity enables markets but does not guarantee returns
- **Thread 3:** Tokenization — from art to finance, the technology is finding its real use cases

*These three threads weave together into one insight: digital ownership is infrastructure, not a product.*

## Five reflection questions:

1. Do you own any digital asset that would survive if the platform closed?
2. Would you pay more for an NFT stored on Arweave vs a centralized server?
3. Should creator royalties be enforced at the protocol level?
4. Is tokenized real estate a security? How would you decide?
5. What asset class will be tokenized next — and why?

## Coming next in the full course:

- **L21** — NFT Technology Deep Dive
- **L22** — NFT Metadata & IPFS
- **L23** — NFT Marketplaces
- **L24** — Lab: OpenSea Analysis
- **L25** — Digital Art & Collectibles
- **L26** — Gaming NFTs & Metaverse
- **L27** — RWA Tokenization

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## Quiz: Questions 1–5

**Q1. The term “non-fungible” means the token is:**

- A) Worthless and cannot be sold
- B) Unique and not interchangeable with another token of the same type
- C) Stored entirely on the blockchain
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**Answer: B** – Non-fungible means each token is unique; unlike ETH or USDC, one NFT cannot be swapped 1:1 for another.

**Q2. What information does an NFT actually store on the blockchain?**

- A) The full image file and metadata
- B) Only the owner’s real-world identity
- C) Token ID, owner address, and a URI pointing to off-chain metadata
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**Q3. What is the key difference between ERC-721 and ERC-1155?**

- A) ERC-721 is newer and more efficient
- B) ERC-1155 supports both fungible and non-fungible tokens in one contract
- C) ERC-721 works on any blockchain; ERC-1155 is Ethereum-only
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**Q4. The purpose of the tokenURI function in ERC-721 is to:**

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**Answer: D** – tokenURI returns a URL (often IPFS) pointing to a JSON file with the token’s name, description, and image link.

**Q5. An NFT’s metadata is stored on a centralized server. The server goes offline permanently. What happens?**

- A) The token is automatically deleted from the blockchain
- B) The token transfers to the server operator
- C) The token persists on-chain, but the art and metadata are lost
- D) Nothing — the blockchain stores a backup copy

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- B) ERC-1155 supports both fungible and non-fungible tokens in one contract
- C) ERC-721 works on any blockchain; ERC-1155 is Ethereum-only
- D) There is no meaningful difference

**Answer: B** – ERC-1155 is a multi-token standard that handles both unique items and fungible currencies in a single contract.

**Q4. The purpose of the tokenURI function in ERC-721 is to:**

- A) Transfer ownership of the token
- B) Verify the buyer’s identity
- C) Burn the token permanently
- D) Return a link to the off-chain metadata JSON describing the token

**Answer: D** – tokenURI returns a URL (often IPFS) pointing to a JSON file with the token’s name, description, and image link.

**Q5. An NFT’s metadata is stored on a centralized server. The server goes offline permanently. What happens?**

- A) The token is automatically deleted from the blockchain
- B) The token transfers to the server operator
- C) The token persists on-chain, but the art and metadata are lost
- D) Nothing — the blockchain stores a backup copy

**Answer: C** – The on-chain token survives forever, but it now points to a dead link — you own a receipt to nothing.

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Questions 1–5 test Understand and Apply levels: definitions, on-chain vs off-chain, and storage consequences.

**Q6. IPFS addresses content by hash rather than by location. Why does this matter for NFTs?**

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- B) Content-addressed storage ensures the file cannot be swapped — the hash changes if the content changes
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**Q7. In an English auction for an NFT, the winning bidder is:**

- A) The person who places the highest bid before time expires
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**Answer: A** – English auctions award the item to the highest bidder, the same model used by Christie's and Sotheby's.

**Q8. A collection mints 10,000 NFTs at 0.08 ETH each. What is the total mint revenue?**

- A) 80 ETH
- B) 800 ETH
- C) 8,000 ETH
- D) 80,000 ETH

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**Answer: B** –  $10,000 \times 0.08 = 800$  ETH. At \$2,500/ETH this equals \$2,000,000 in mint revenue.

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- A) Royalty payments increase because buyers feel generous
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**Answer: D** – When Blur made royalties optional, aggregate creator royalty revenue collapsed by over 90%.

**Q10. Axie Infinity's SLP token dropped from \$0.39 to \$0.003. What is the percentage loss?**

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**Answer: C** – Loss =  $(0.39 - 0.003) / 0.39 = 0.387/0.39 = 99.2\%$ . Virtually the entire value was destroyed.

Questions 6–10 test Apply level: IPFS mechanics, auction types, calculations, and market dynamics.

## Quiz: Questions 11–15

**Q11. CryptoPunks have a floor price of 50 ETH at \$2,500/ETH. With 10,000 punks, what is the implied collection value?**

- A) \$1.25 billion   B) \$125 million   C) \$500 million   D) \$2.5 billion

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**Q13. Why did NFT royalty enforcement collapse across marketplaces?**

- A) Ethereum changed its protocol to remove royalty support  
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**Q14. What was the fundamental structural flaw in Axie Infinity's Play-to-Earn model?**

- A) The game was too difficult for casual players  
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**Answer: B** – Existing player income depended on new entrants buying in; when growth stalled, the economy collapsed.

**Q15. Storing NFT art fully on-chain is more permanent but less practical. Why?**

- A) On-chain art looks worse than off-chain art B) Ethereum does not support image formats  
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**Answer: D** – Ethereum storage costs \$20,000–\$40,000 per MB; even a small image would cost thousands of dollars in gas.

Questions 11–15 test Apply and Analyze levels: valuation calculations, royalty dynamics, and P2E economics.

## Quiz: Questions 16–20

**Q16. RWA tokenization started with Treasury bonds rather than real estate. Why?**

- A) Treasuries have simpler legal structures, are fungible, and have clear regulatory frameworks
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**Q17. The NFT market crashed 90% from its 2021 peak. Does this mean the technology failed?**

- A) Yes — a 90% crash proves NFTs have no value
- B) Yes — the technology was fundamentally flawed from the start
- C) No — the speculation failed, but the underlying technology continues to develop with new use cases like RWA
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**Answer: C** – Speculative bubbles and underlying technology are distinct; the internet bubble crashed 78% but the web survived.

**Q18. An NFT collection uses IPFS for metadata, but no one is pinning the files. What happens long-term?**

- A) IPFS automatically keeps all files forever
- B) The metadata becomes unretrievable and the token is orphaned
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**Q19. A project offers 20% APY on staked NFTs, has an anonymous team, and stores metadata on a personal server. Should you invest?**

- A) Yes — 20% APY is an excellent return
- B) Yes — anonymous teams protect developer privacy
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**Answer: D** – Three red flags: unrealistic yield (likely unsustainable), anonymous team (no accountability), centralized storage (metadata at risk).

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- A) No — real estate tokens are always exempt from securities law
- B) Yes — investors expect profits from the efforts of others (the property manager), satisfying the Howey test
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**Answer: B** – The Howey test asks: investment of money, common enterprise, expectation of profits, from efforts of others. All four are met.

Questions 16–20 test Analyze and Evaluate levels: RWA design, bubble interpretation, and investment decisions.