# Lesson 20: Tokens – ERC-20 and NFTs

## Module 2: Blockchain Fundamentals

Digital Finance

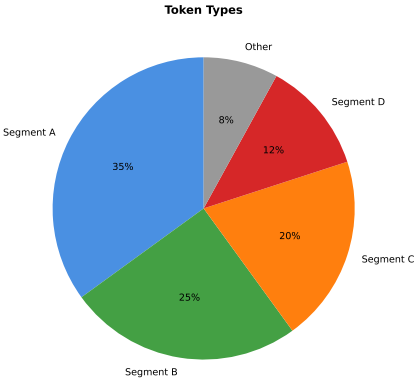
# What is a Token?

**Definition:**

- Digital asset on blockchain
- Smart contract manages ownership
- Not native currency (e.g., not ETH)
- Programmable properties

**Types:**

- **Fungible:** Interchangeable (e.g., USDC, UNI)
- **Non-Fungible:** Unique (e.g., NFTs, real estate)
- **Semi-Fungible:** Hybrid (e.g., gaming items)

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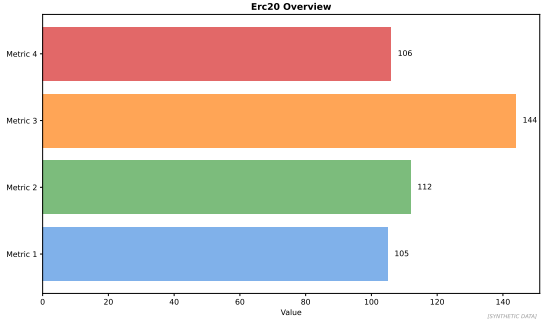
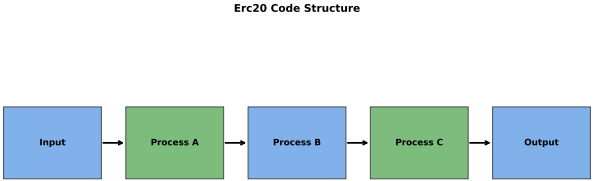
# ERC-20: Fungible Token Standard




**Standard Functions:**

- `totalSupply()`: Returns total token supply
- `balanceOf(address)`: Returns balance of account
- `transfer(to, amount)`: Send tokens
- `approve(spender, amount)`: Allow third party to spend
- `transferFrom(from, to, amount)`: Third-party transfer (after approval)

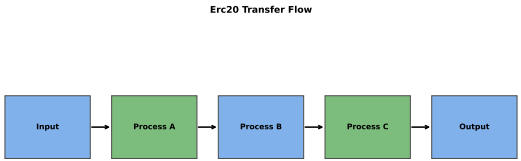
# ERC-20 Implementation Example




**Key Components:**

- **State Variables:** `balances`, `allowances`, `totalSupply`
- **Events:** `Transfer(from, to, amount)`, `Approval(owner, spender, amount)`
- **Metadata:** Name, symbol, decimals (usually 18)

# ERC-20 Transfer Flow




**Direct Transfer:**

1. User calls `transfer(recipient, 100)`
2. Contract checks balance
3. Updates `balances[sender] -= 100`, `balances[recipient] += 100`
4. Emits `Transfer` event

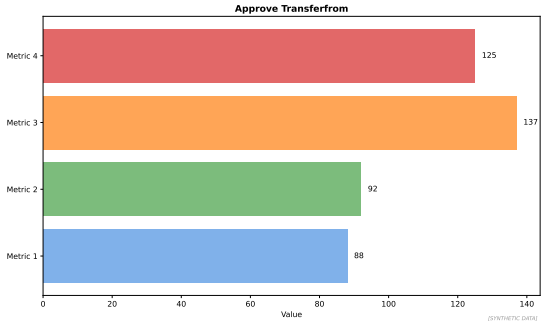
# Approval and TransferFrom Pattern

**Use Case:**

- Allow smart contract to spend your tokens
- Required for DeFi (DEXs, lending)
- Two-step process

**Steps:**

1. User approves DEX: `approve(DEX, 1000)`
2. DEX calls: `transferFrom(user, pool, 500)`
3. Check allowance, transfer tokens




**Security Note:** Approve 0 before changing allowance to prevent race conditions

# Popular ERC-20 Tokens (2024)

| Token | Symbol | Market Cap | Use Case |
|---|---|---|---|
| Tether | USDT | $100B+ | Stablecoin (pegged to USD) |
| USD Coin | USDC | $30B+ | Regulated stablecoin |
| Uniswap | UNI | $5B+ | DEX governance token |
| Chainlink | LINK | $8B+ | Oracle network payments |
| Wrapped Bitcoin | WBTC | $10B+ | Bitcoin on Ethereum |

**Total ERC-20 Tokens:** >500,000 deployed on Ethereum

# Token Utility: Why Create Tokens?

**Governance:**

- DAO voting rights (e.g., UNI, COMP)
- Protocol parameter changes
- Treasury allocation

**Access:**

- Platform access (e.g., Filecoin storage)
- Fee discounts (e.g., BNB on Binance)
- Staking for rewards

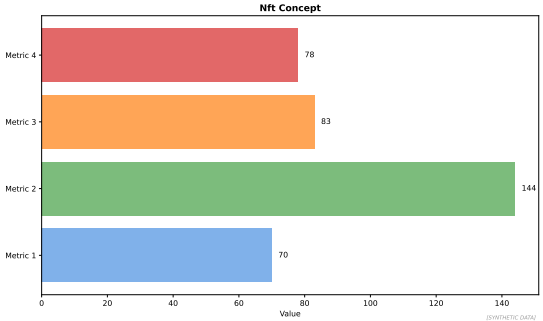
**Incentives:**

- Liquidity mining rewards
- Early adopter benefits
- Network effects

**Speculation:**

- Investment asset
- Price appreciation
- Trading on exchanges

# NFTs: Non-Fungible Tokens




**Key Properties:**

- **Unique:** Each token has distinct identifier (tokenId)
- **Indivisible:** Cannot split (unlike ERC-20)
- **Provably Scarce:** Limited supply enforced by contract
- **Metadata:** Points to off-chain data (image, video, properties)

# ERC-721: NFT Standard

**Required Functions:**

- `balanceOf(owner)`: Number of NFTs owned
- `ownerOf(tokenId)`: Who owns specific token
- `transferFrom(from, to, tokenId)`: Transfer NFT
- `approve(to, tokenId)`: Approve transfer
- `safeTransferFrom(...)`: Safe transfer (checks recipient can receive)

**Optional Metadata Extension:**

- `tokenURI(tokenId)`: Returns URL to metadata JSON
- Metadata typically stored on IPFS or centralized server

**Example:** CryptoPunks, Bored Ape Yacht Club, Azuki

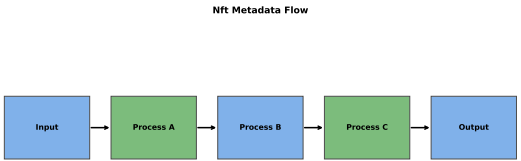
# NFT Metadata Structure

**On-Chain (Contract):**

- Token ID
- Owner address
- Approval state
- Pointer to metadata URI

**Off-Chain (IPFS/Server):**

- Name, description
- Image/video URL
- Attributes (rarity traits)
- Properties




**Centralization Risk:** If server hosting image goes down, NFT becomes broken link

# NFT Use Cases

**Digital Art:**

- Provable ownership
- Royalties on resales (via marketplaces)
- Scarcity enforcement

**Gaming:**

- In-game items (weapons, skins)
- Land ownership (Decentraland)
- Cross-game interoperability

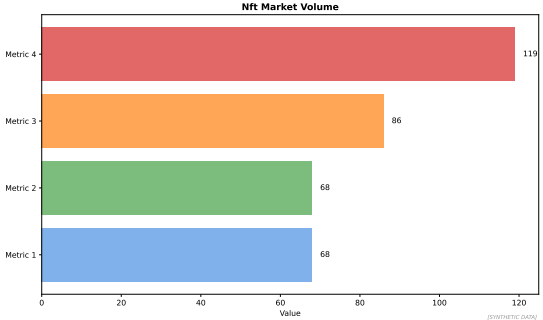
**Identity/Credentials:**

- Digital diplomas
- Membership badges
- Soulbound tokens (non-transferable)

**Real-World Assets:**

- Real estate deeds
- Luxury goods authentication
- Tickets/event access

# NFT Mania: 2021 Boom and Bust




**Peak (Aug 2021 – Jan 2022):**

- Monthly volume: \$5B+ on OpenSea
- Bored Ape floor price: 150 ETH (\$600K)
- Celebrity endorsements, mainstream media

**Crash (2022–2024):** 90%+ decline in volume, floor prices collapsed

# Criticisms of NFTs

- **Ownership Confusion:** You own token, not copyright or image itself
- **Environmental (Pre-Merge):** High energy usage on PoW Ethereum
- **Speculation Bubble:** Most projects have no utility, pure speculation
- **Centralization:** Metadata often on centralized servers, not fully decentralized
- **Money Laundering:** Wash trading, inflated sale prices
- **IP Issues:** Plagiarism, unauthorized minting of others' art
- **Market Manipulation:** Pump-and-dump schemes, insider trading

**Counterargument:** Technology has legitimate use cases beyond JPEGs (credentials, gaming, ticketing)

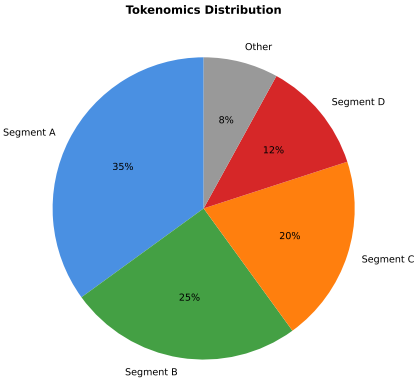
# Tokenomics: Designing Token Economics

**Supply Mechanics:**

- **Fixed Supply:** Bitcoin (21M cap)
- **Inflationary:** Continuous issuance (older Ethereum)
- **Deflationary:** Burn mechanisms (EIP-1559)
- **Elastic:** Rebasing (Ampleforth)

**Distribution:**

- Team allocation (with vesting)
- Investors/VCs (lockup periods)
- Community rewards (airdrops, mining)
- Treasury for governance

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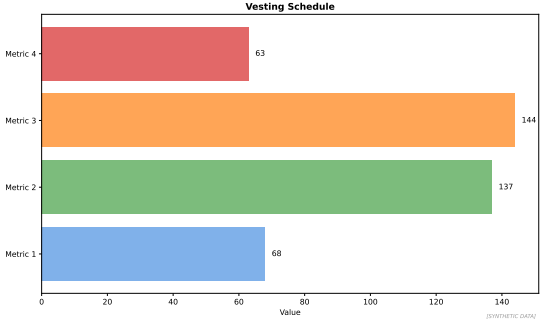
# Vesting and Lock-Ups




**Purpose:** Prevent early investors/team from immediate sell-off (dump)

**Typical Schedule:**

- **Cliff:** 6–12 months (no tokens released)
- **Linear Vesting:** Monthly releases over 2–4 years
- **Example:** 1-year cliff, then 25% per year for 4 years

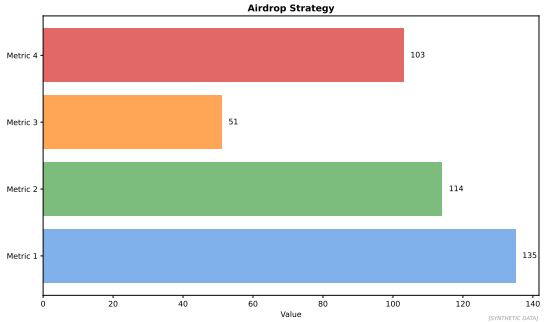
# Airdrops: Free Token Distribution

**Reasons:**

- Reward early users
- Decentralize governance
- Marketing/awareness
- Avoid securities regulations (gift, not sale)

**Famous Examples:**

- Uniswap: 400 UNI to all users ($1200+)
- Ethereum Name Service: Retroactive airdrop
- Arbitrum: Governance token to users



# Token Launch Models

| Model | Mechanism | Pros/Cons |
|---|---|---|
| ICO (2017–18) | Public sale at fixed price | Simple, but many scams, regulatory issues |
| IEO (2019) | Sale on exchange (e.g., Binance Launchpad) | Vetted, but centralized |
| Fair Launch (2020) | No pre-sale, everyone equal | Community-driven, but vulnerable to bots |
| LBP (2021) | Liquidity Bootstrapping Pool (declining price) | Price discovery, less FOMO |

**Trend:** Moving away from ICOs toward fairer, community-first models

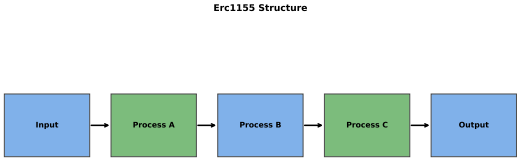
# ERC-1155: Multi-Token Standard

**Innovation:**

- Single contract manages multiple token types
- Fungible, non-fungible, semi-fungible
- Batch operations (gas efficient)

**Use Case: Gaming**

- Gold (fungible)
- Sword #123 (non-fungible)
- Health potion (semi-fungible, limited)
- All in one contract

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# Token Security: Common Vulnerabilities

- **Reentrancy:** External calls before state updates (use checks-effects-interactions)
- **Integer Overflow/Underflow:** Fixed in Solidity 0.8+ (automatic checks)
- **Approval Race Condition:** Approve 0 before changing allowance
- **Unchecked Return Values:** ERC-20 transfer may silently fail
- **Front-Running:** Miners/bots see pending transactions, exploit
- **Centralization:** Owner has mint/burn/pause powers (rug pull risk)

**Best Practice:** Use OpenZeppelin audited contracts, multiple audits, time-locks on admin functions

# Summary

- **ERC-20:** Fungible token standard, balances, transfer, approve/transferFrom
- **ERC-721 (NFTs):** Unique tokens, digital art/collectibles/gaming
- **NFT Metadata:** On-chain ownership, off-chain images (IPFS/centralized)
- **Tokenomics:** Supply, distribution, vesting, airdrops
- **ERC-1155:** Multi-token standard, efficient for gaming
- **Security:** Reentrancy, overflows, centralization risks

**Next Lesson:** DeFi Fundamentals – AMMs, liquidity pools, lending protocols