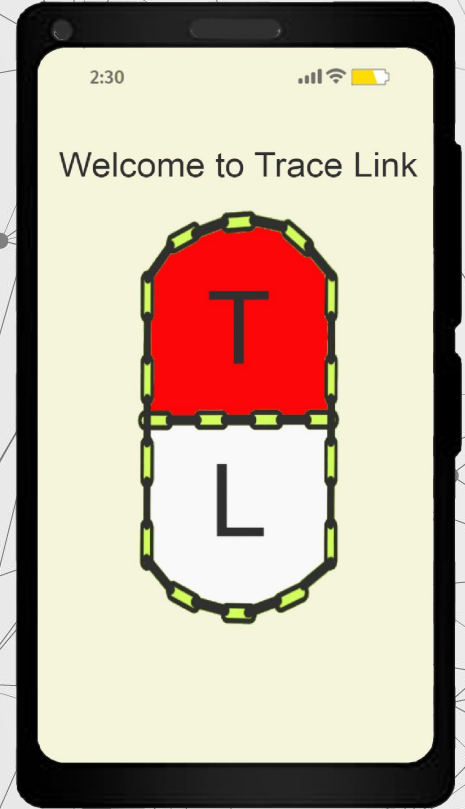# FELIX NG
CEO & FOUNDER

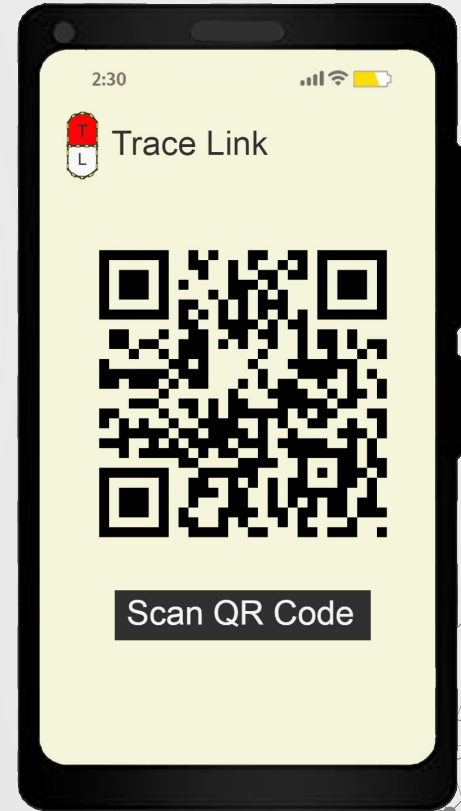Trace Link - The Future of Supply Chain Management

AIM

In the pharmaceutical industry there has been a lot of counterfeiting drugs that has increased the amount of medicine trafficking. The World Health has shown that 11% of medications sold in developing countries have been counterfeit, resulting in 144,000 annual deaths(White, 2022). Drug counterfeiting is a $200-billion business which is financially damaging to the authentic manufacturers and is life threatening to patients(Miller & Duggan, n.d.). One of the most commonly counterfeit drugs are weight loss drugs such as Lipitor(Haiken, n.d.). To prevent counterfeit drugs, the pharmaceutical industry needs an efficient supply chain management system to protect the consumers of the medicine. This would avoid counterfeit medical drugs from entering the global market.

DEMO

Agreements between all stakeholders are stored via the smart contract. Smart Contracts are implemented into TraceLinks blockchain to enforce agreement between each stakeholder in the supply chain. The smart contract will contain conditions such as the legality and reliability of the source of the drug and its components. The Manufacturer of the drugs will provide a unique QR code which is the public key for every pharmaceutical product they produce as that will be the identity of this digital asset. The private key of each stakeholder is stored off-chain. The next stakeholder will scan that QR code to view the information about that product and to execute the smart contract to ensure its authenticity so it can be purchased safely, at the same time it will update the trading history of that particular product. Each stakeholder will be able to know that their product was safely received by the client.
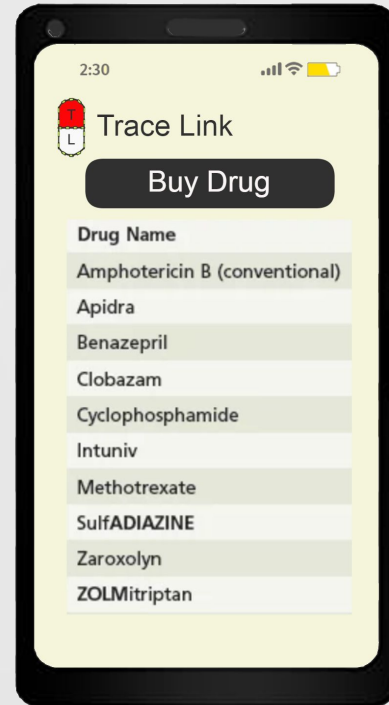
2:30

Trace Link

Scan QR Code

BENEFITS

TraceLink makes it very easy to trace trading history to identify source of counterfeitting. This simultaneously prevents other ethical problems in supply chain management such as child labour, modern slavery, toxic waste etc. The data in blockchain network is immutable so information about the drug cannot be tampered with. This means that the information on the drug can be trusted and therefore the source of that drug can be deemed reliable. TraceLink is a distributed decentralised system so peers in a network cannot force contracts to be initialised, this is one of the main benefits of decentralisation. The removal of the middle man results in less cost and human error since the smart contract is used for verification rather than a memeber in the network.
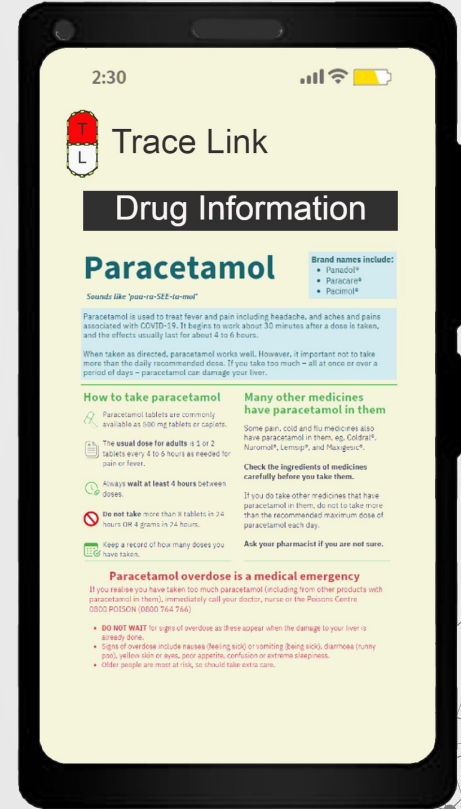
FUNCTIONALITY

With the assistance of the TraceLink Prototype, the owner of the drug that is created by the manufacturer is being changed if and only if every property of the drug is the same, if for some reason the drug has had ingredients added into it then the smart contract will pick up on that and throw and error before creating a new block. This applies to all properties of the drug. If nothing has changed then a transaction of ownership is made along the supply chain and that transaction is recorded in the blockchain network. I have set up the prototype to have predetermined stakeholders so the drug can only be transferred in one ordered series between the stakeholders, this is how a supply chain would behave in real world logistics.

2:30

Trace Link

Buy Drug

Drug Name
Amphotericin B (conventional)
Apidra
Benazepril
Clobazam
Cyclophosphamide
Intuniv
Methotrexate
SulfADIAZINE
Zaroxolyn
ZOLMitriptan

2:30

Trace Link

Sell a Drug

Rank	Drug (Brand Name)	Primary use	Annual sales 10/1/12- 9/30/13
1	Abilify	depression/ mental/mood disorders	$6,391,050,009
2	Nexium	acid reflux/ulcers	$6,086,840,503
3	Cymbalta	depression/ mental/mood disorders	$5,432,152,672
4	Humira	inflammation: arthritis	$5,352,226,238
5	Crestor	statin: cholesterol	$5,318,542,115
6	Advair Diskus	inflammation: bronchial	$5,114,309,392
7	Enbrel	inflammation: joints/skin	$4,673,141,322
8	Remicade	inflammation: joints/bowels/skin	$4,058,128,532
9	Copaxone	multiple sclerosis	$3,788,545,102
10	Neulasta	to increase white blood cells	$3,537,574,204

WEBSITE

Website Link: https://felixng2003.wixsite.com/tracelink

WEBSITE

Website Link: https://felixng2003.wixsite.com/tracelink

WEBSITE

Website Link: https://felixng2003.wixsite.com/tracelink

CODE

The name of the contract is Stakeholder, it contains fields that store the address for each stakeholder and the current stakeholders name and address. There is a List collection type that holds the drug object. There is also a count variable that keeps count of the number of drugs going through the supply chain. Default parameters are set for testing and demonstration purposes. Errors are initialised for error handling for certain events.

Logistics Demo: https://youtu.be/5VatKbDVCjM
Full Code Demo: https://youtu.be/xJ6attzQGF8
Payment Demo: https://youtu.be/BmW22xyr3CI

```solidity
// SPDX-License-Identifier: GPL-3.0
// Author: Felix Ng
pragma solidity >=0.7.0 <0.9.0;
import "hardhat/console.sol";

contract Stakeholder {

    address private stakeholderAddr;
    string private stakeholderName;
    //every stakeholder has some drug
    Drug[] private SHdrugs;
    //other metrics
    uint private numDrugs;

    //could add function to move stakeholders automatically
    address private manufacturer = 0x5B38Da6a701c568545dCfcB03FcB875f56beddC4;
    address private wholesaler = 0xAb8483F64d9C6d1EcF9b849Ae677dD3315835cb2;
    address private pharmacist = 0x4B20993Bc481177ec7E8f571ceCaE8A9e22C02db;
    address private patient = 0x78731D3Ca6b7E34aC0F824c42a7cC18A495cabaB;

    //default drug information
    string private f_name = "Paracetamol";
    string private f_ingred = "Acetylation of Para-aminophenol";
    uint private f_dos = 2;
    string private f_warn = "Out of reach of children";
    string private f_manufac = "PSM Healthcare";
    bool private f_init = true;

    //events and errors for certain events
    event drugTransfer(address indexed oldStakeholder, address indexed newStakeholder);
    error endUserReached(string message);
    error illegalSubstance(string message);
    error tooManyDrugs(string message);

    //initalise the smart contract
    constructor() public payable{
        payer = payable(msg.sender);
        //alarms console
        console.log("Stakeholder contract deployed by:", manufacturer);
        //sets variables
        stakeholderAddr = manufacturer;
        stakeholderName = "Manufacturer";
        getStakeholder();
        emit drugTransfer(address(0), stakeholderAddr);
        //creates the drug on initiation of contract
        createDrug();
    }
}
```

CODE

The changeStakeholder() method is the functionality of the smart contract which runs checks to see if all the proporties of the drug is safe by calling the method safeDrug() which is a method defined in the code that checks for all the properties of the drug and returns a boolean for if the drug has been tampered with or not. The Drug object is constructed using the struct object type in solidity, I chose to use struct so I can assign the objects certain properties I wanted it to have. I then mapped the drug object to a integer that acts as the key of the drug object. When the drug is initialised its properties are assigned.

```solidity
//Changes the stakeholder of the drug
function changeStakeholder(address newStakeholderAddr) private{
    if(safeDrug()){
        //determines stakeolder name
        if(newStakeholderAddr == manufacturer){
            stakeholderName = "Manufacturer";
        } else if(newStakeholderAddr == wholesaler){
            stakeholderName = "Wholesaler";
        } else if(newStakeholderAddr == pharmacist){
            stakeholderName = "Pharmacist";
        } else if(newStakeholderAddr == patient){
            stakeholderName = "Patient";
        }
        emit drugTransfer(stakeholderAddr, newStakeholderAddr);
        //renaming will change the ownership of the drug as we only have one instance
        stakeholderAddr = newStakeholderAddr;
    } else {
        revert illegalSubstance("Thats not allowed!");
    }
}

//Drug object
struct Drug {
    string name;
    string ingred;
    uint dos;
    string warn;
    string manufac;
    bool init;
}

//creates only one drug for now but could be any kind in the world
mapping (uint => Drug) private Drugs;
function createDrug() private {
    //pre check for testing demonstration purposes
    if(numDrugs == 1){
        revert tooManyDrugs("One drug at a time is allowed to pass through the supply chain");
    }
    Drug memory d = Drugs[0];
    d.name = f_name;
    d.ingred = f_ingred;
    d.dos = f_dos;
    d.warn = f_warn;
    d.manufac = f_manufac;
    d.init = f_init;
    SHdrugs.push(d);
    numDrugs = 1;
}
```

CODE

In a real world logistics the product is transferred from one stakeholder to another only is payment is received. Each stakeholder needs to sell the drug down the supply chain. I have implemented this payment system using Ethers which is the Ethereum cryptocurrency. If this platform were to be implemented in the real world the currency would not necessarily be Ethers it may not even be any kind of crypto currency at all. But for proof of stake I have used Ethers here in this program. Due to this project only being a prototype the payment mechanism is implemented between 2 stakeholders only, the manufacturer and the wholesaler. To complete the platform we would apply this same mechanism to all stakeholders.

```solidity
function safeDrug() private view returns (bool) {
    //name
    string memory name_a = SHdrugs[0].name;
    string memory name_b = f_name;
    //ingredients
    string memory ingred_a = SHdrugs[0].ingred;
    string memory ingred_b = f_ingred;
    //dosage
    uint dos_a = SHdrugs[0].dos;
    uint dos_b = f_dos;
    //warning
    string memory warn_a = SHdrugs[0].warn;
    string memory warn_b = f_warn;
    //manufactuer
    string memory manufac_a = SHdrugs[0].manufac;
    string memory manufac_b = f_manufac;
    //initialisation
    bool init_a = SHdrugs[0].init;
    bool init_b = f_init;
    if(keccak256(abi.encodePacked((name_a))) == keccak256(abi.encodePacked((name_b))) &&
    keccak256(abi.encodePacked((ingred_a))) == keccak256(abi.encodePacked((ingred_b))) &&
    dos_a == dos_b &&
    keccak256(abi.encodePacked((warn_a))) == keccak256(abi.encodePacked((warn_b))) &&
    keccak256(abi.encodePacked((manufac_a))) == keccak256(abi.encodePacked((manufac_b))) &&
    init_a == init_b &&
    msg.value < 50){
        console.log("Drug is safe");
        return true;
    } else {
        console.log("Drug is unsafe!");
        return false;
    }
}

//default payable addresses and cost of drugs
address payable private payer;
address payable private payee = payable(wholesaler);
uint private drugCost = msg.value;
mapping(address => uint) private deposits;
//transfer the money for the drug
function transfer() public payable{
    //Eth transfer deposit
    deposits[payee] = deposits[payee] + drugCost;
    //withdraw
    uint payment = deposits[payee];
    deposits[payee] = 0;
    payee.transfer(payment);
}
```

LOGISTICS
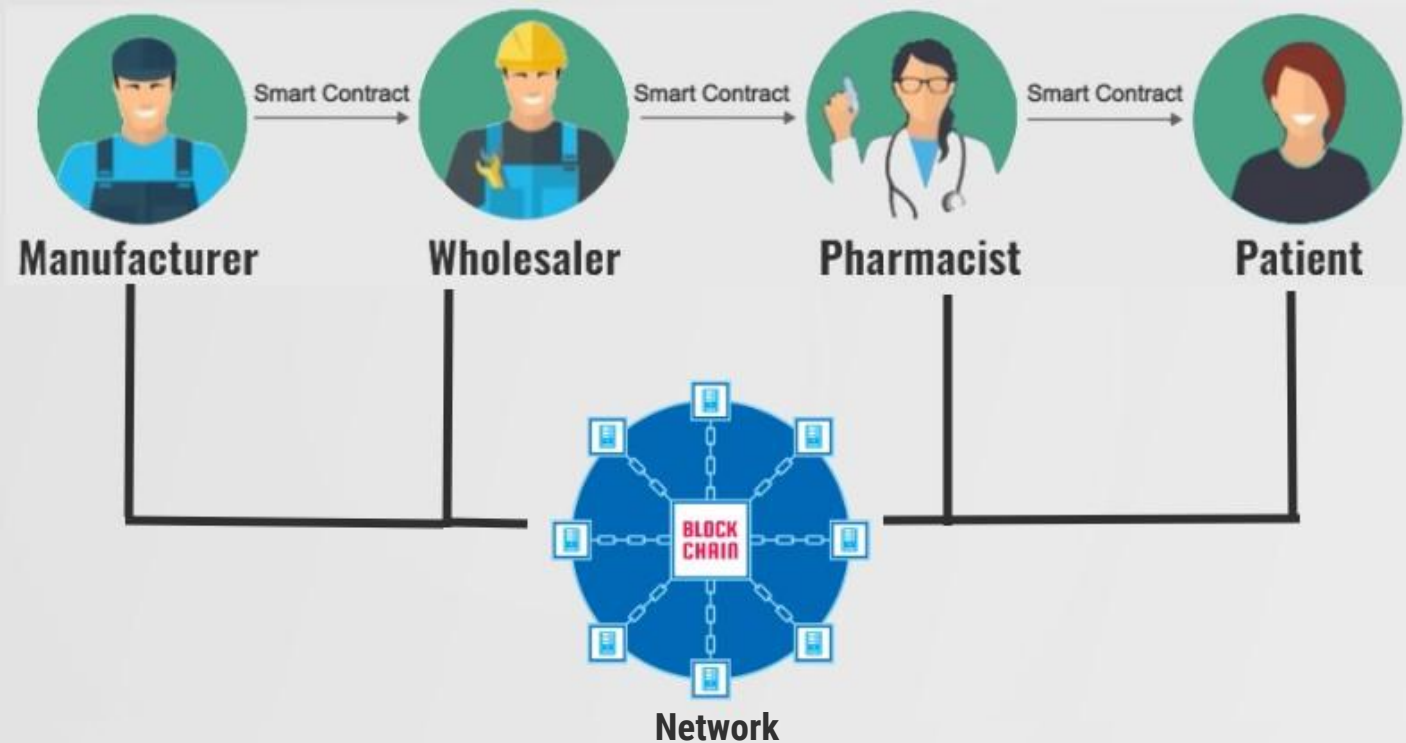
DO WE NEED A BLOCKCHAIN?

The key reasons for having a blockchain include: Requirements for a fast transaction between one member to another. Secure transaction so members know information is not tampered with. The members in the network do not trust each other. A Logistic company would benefit from using TraceLink as thier supply chain management system because traditional supplychain suffer from those problems listed above and TraceLink implements the solutions to them using blockchain technology. Trace Link also helps to comply with Legislations around supply chains such as transparacy of the supply chains to prevent modern slavery. Current problems traditional supply chains are facing include mapping intricate supply chain relationships, tracing final products and individual components, identifying where and to what extent child labour occurs.(Safety, Addressing modern slavery and worker exploitation in supply chains: agreement to release public consultation document, 2022) With TraceLink these legislations would be met.
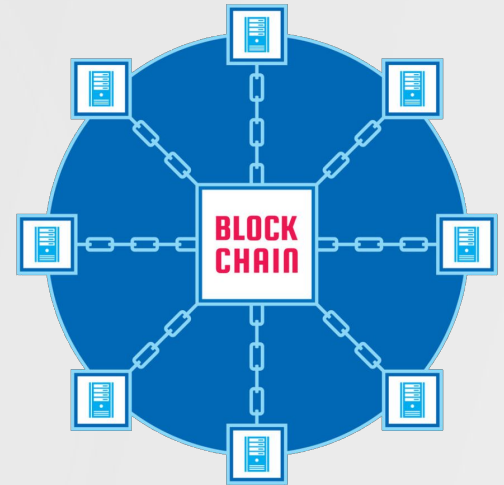
CULTURAL CONSIDERATIONS

With the ability to trace transaction along the supply chain, stakeholders can work towards reducing carbon footprints and time spent in transit(Rawat, 2021). TraceLink allows for a channel which stakeholders can use to generate metrics around how much energy or time they are using to transport the product. With easy traceability, COVID19 tracing becomes a lot easier when finding out the transaction where infection occurred in the supply chain. TraceLink's traceability features allow for stakeholders to prevent interactions between certain stakeholders that are prone to infection or to find out which stakeholder was infected first. TraceLinks system is inclusive, allowing for everyone in the logistics to have a voice. Human Error is reduced by removal of the middle man and the TraceLink app make it use friendly for stakeholders to interact with the blockchain network. With the implementation of smart contracts, transactions are able to be made in this trustless system of supply chains.

CHALLENGES

The cost of maintaining and running blockchain nodes is expensive(Rawat, 2021). To buy an entire ledger is extremely expensive for most companies to afford. Blockchain technology is very new remains undefined most companies will not be willing to move their infrastructure to a blockchain network as it is costly and risky. Distributed systems are public and some pharmaceutical companies value their privacy for competition reasons(Rawat, 2021). This lack of privacy can also be beneficial from a ethical standpoint whereby transparency is expected from consumers to enforce a particular belief in society. Some members may disagree with this transparency while some will not. The blockchain technology becomes useless if the components of the drug were tampered with before reaching the manufacturer(Rawat, 2021). This means the network is only effective within itself. If false tampered information is feed into the network then we would also get false tampered information coming out which is very misleading.
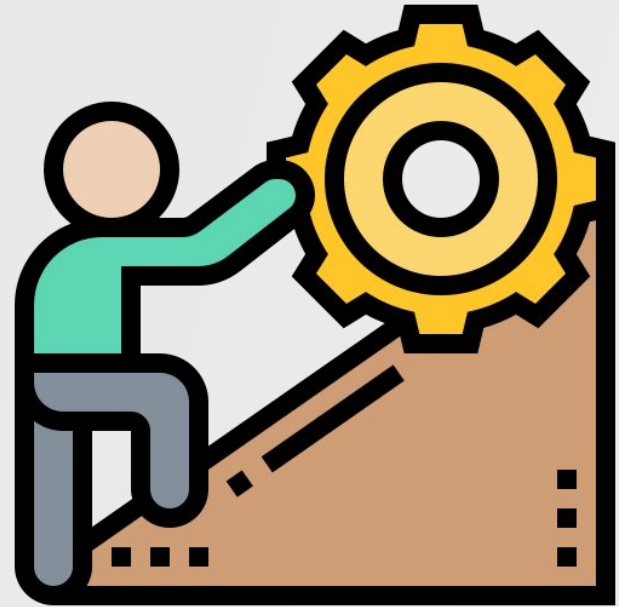
REGULATIONS

It is suggested that the public sector enables public regulatory influence to flow through the combination of legal and technical codes. However issues with this included in a decentralised network is that there is no clear way of shutting down the system which complicates the legal landscape. Governments may do better by regulating technologies like blockchain and acting as a collaborative peer with society rather than having a hierarchy of governance.(Yeoh, 2017) Smart contracts act as an agreement between all stakeholders, this needs to be implemented as well as lawyer involvement in order for a decentralised system like TraceLink to work.(Hawkins, 2022) The smart contract also removes the middle man involvement in the logistics meaning there is less people involved in the system implying there would be less regulations required for the system to function. Smart contracts also handle the prescription process which is especially useful in COVID19 times where a middle man would be completely in-accessible.

LEGISLATIONS

There requires a separate legal contract on the implementation, governance, funding and maintenance of the supply chain using blockchain technology. There must be a contract between which sub suppliers can join the blockchain network. Disclosure of information from a specific stakeholder must be agreed upon by all stakeholders when entering the network. If payments are automatically made via the smart contract then product acceptance needs to be very precise to prevent breach of contracts. All members must agree on thresholds or conditions that prevent a member from claiming force majeure to ensure compliance with the smart contracts. In the event of termination of the smart contract there must be another contract in place agreed upon by all members which protects the rights and responsibilities of every member. On the service level agreements, data from the blockchain is considered trusted, so that data may be used by members as a part of that agreement.(Casper et al. , 2021) Transparency of the supply chain is another legislation set in place by New Zealand Ministry of Business, Innovation and Employment.

GOING FORWARD

In closing one area of concern the association of the digital asset of the drug and the physical asset. In the event of a physical intervention the blockchain network is helpless. We may also want to consider implementing a smart contract to the input of the blockchain network to make sure that sub stakeholders are reliable, this can include ingredient manufacturers for drug manufacturers. We may also want to implement a smart contract for stakeholders who wish to join the network. This is to make sure that stakeholders are qualified to be the stakeholder which they claim to be. We also want to make sure that the network is flexible can is fully capable on growing by taking on new stakeholders at any one time because in a real logistic system stakeholders would be put in and taken out depending on a range of factors. As a decentralised system we want to make sure that all members have a say in the agreements of a smart contract so we want to enforce verification processes around the involvement of all members in the network.

VISUAL REFERENCES

Arif, S. A. (2013). Available drug information on the Internet: A focus on vetted sites. Retrieved from Healio: https://www.healio.com/news/cardiology/20150821/10_3928_1081_597x_20130101_00_1166969

Clip Art Max. (n.a.). DMCA Report Reverse Image Search. Retrieved from Clip Art Max: https://www.clipartmax.com/middle/m2i8d3Z5N4A0b1Z5_target-free-icon-objective-icon/

Deztanee. (n.a.). Building Cartoon. Retrieved from CleanPNG: https://www.cleanpng.com/png-chain-link-building-clip-art-4289538/

Eucalyp. (n.a.). Challenges free icon. Retrieved from Flat Icon: https://www.flaticon.com/free-icon/challenges_1934019

free png logos. (n.a.). QR Code Transparent PNG Images Free Download. Retrieved from free png logos: https://www.freepnglogos.com/pics/qr-code

Kalyansinh. (n.a.). Culture Area. Retrieved from Clean PNG: https://www.cleanpng.com/png-culture-clip-art-2021455/

khosq. (n.a.). Legislation. Retrieved from khosq: https://khosq.am/en/legislation/

Larry , W., Peter, M., Dawen, K., & Michael, W. (2015). Separation Science in Drug Development, Part IV: Quality Control. Retrieved from: https://www.chromatographyonline.com/view/separation-science-drug-development-part-iv-quality-control

Health Navigator New Zealand. (n.a.). Paracetamol. Retrieved from Health Navigator New Zealand: https://www.healthnavigator.org.nz/medicines/p/paracetamol/

Seek PNG. (n.a.). Regulation - Rules And Regulation Icon. Retrieved from Seek PNG: https://www.seekpng.com/ipng/u2t4y3o0i1r5i1w7_regulation-rules-and-regulation-icon/

Serkorkin. (n.a.). Blockchain technology - vector logo template concept illustration. Abstract geometric business sign. Retrieved from Dreams Time: https://www.dreamstime.com/blockchain-technology-vector-logo-template-concept-illustration-abstract-geometric-business-sign-digital-crypto-currency-creative-image104613000

Source Map . (n.a.). What is Supply Chain Mapping? Retrieved from Source Map : https://sourcemap.com/news/what-is-supply-chain-mapping

Stick PNG. (n.a.). Download Growth Arrow transparent PNG. Retrieved from Stick PNG: http://www.stickpng.com/img/miscellaneous/symbols/growth-arrow
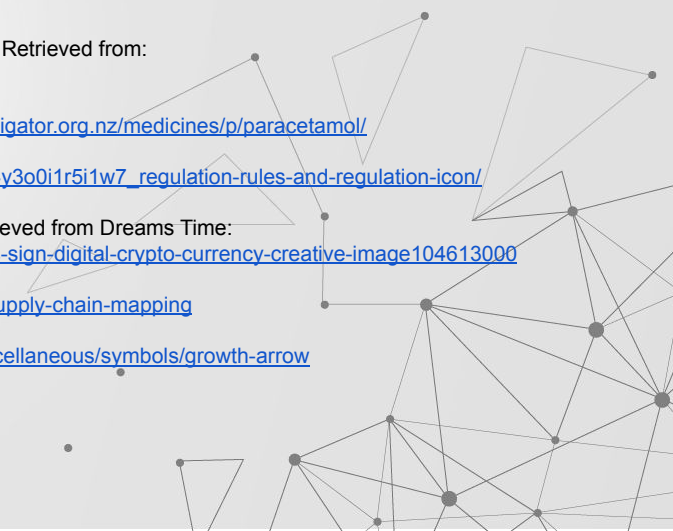
TEXT REFERENCES

Explained, S. (Director). (2017). Smart contracts - Simply Explained [Motion Picture].
https://www.youtube.com/watch?v=ZE2HxTmxfrI

getsmarter. (2022). How Blockchain Will Radically Improve the Supply Chain. Getsmarter.
https://www.getsmarter.com/blog/market-trends/how-blockchain-will-radically-improve-the-supply-chain/

Haiken, M. (n.d.). 7 Most Common Counterfeit Drugs. Safe Medicines.
https://www.safemedicines.org/2012/08/7-most-frequently-counterfeited-medicines-are-scary462.html

Market Intelligence Blogs. (2022). A Brief Guide To Smart Contracts For Supply Chains. GEP.
https://www.gep.com/blog/mind/guide-to-smart-contracts-for-supply-chain#:~:text=Smart%20contracts%20are%20automatically%20triggered,payment%20into%20a%20holding%20account.

Melanie. (2020). Centralised vs. decentralised supply chains — the pros and cons. Unleashed.
https://www.unleashedsoftware.com/blog/centralised-vs-decentralised-supply-chains-the-pros-and-cons

Mikulic, M. (2021). Total number of counterfeit incidents concerning pharmaceuticals worldwide from 2002 to 2021. Retrieved from Statista :
https://www.statista.com/statistics/253150/counterfeit-incidents-concerning-pharamceuticals-since-2002/

Miller, G., & Duggan, E. (n.d.). Optimizing your data for the reimagined drug supply chain. Fierce Pharma.
https://www.fiercepharma.com/special-report/top-counterfeit-drugs-report#:~:text=The%20erectile%2Ddysfunction%20treatments%20Viagra,teams%20to%20track%20down%20counterfeiters.

Ofori-Parku, S. S. (2022). Fighting the global counterfeit medicines challenge: A consumer-facing communication strategy in the US is an imperative. Journal of Global Health, 12.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9031510/

Rawat, S. (2021). Blockchain Makes Biotech Supply Chains Traceable. LabioTech.
https://www.labiotech.eu/in-depth/blockchain-biotech-supply-chain/

Rosencrance, L. (2020). 7 real-life blockchain in the supply chain use cases and examples. TechTarget .
https://www.techtarget.com/searcherp/feature/4-key-blockchain-in-supply-chain-use-cases-and-examples

White, C. M. (2022). Dangerous Counterfeit Drugs are Putting Millions at Risk, a New Study Says. University Of ConnectIcut.
https://today.uconn.edu/2022/06/dangerous-counterfeit-drugs-are-putting-millions-at-risk-a-new-study-says/

Haq, I. (2018). Blockchain Technology in Pharmaceutical Industry to Prevent Counterfeit Drugs. International Journal of Computer Applications.
https://www.researchgate.net/profile/Ijazul-Haq/publication/323872197_Blockchain_Technology_in_Pharmaceutical_Industry_to_Prevent_Counterfeit_Drugs/links/5acc9154a6fdcc8bfc87e5f4/Blockchain-Technology-in-Pharmaceutical-Industry-to-Prevent-Counterfeit-Drugs.pdf

TEXT REFERENCES

Safety, O. o. (2022). Addressing modern slavery and worker exploitation in supply chains: agreement to release public consultation document. Ministry of Business, Innovation and Employment.
https://www.mbie.govt.nz/dmsdocument/19920-addressing-modern-slavery-in-supply-chains-further-decisions-for-public-consultation-annex-five-literature-review-on-the-impact-and-effectiveness-of-modern-slavery-legislation-proactiverelease-pdf

Casper, R. H., Ellis, N. J., Gehl, K. E., Haas, E. A. N., Lanza, J. D., Millendorf, S. M., Miller, V. L., Tantleff A. K., Wang, E., Wegrzyn, K. E. (2021). Legal Implications of Blockchain in Supply Chain: What's Law Got to Do With It? Foley & Lardner LLP.
https://www.foley.com/en/insights/publications/2021/10/legal-implications-of-blockchain-in-supply-chain

Hawkins, L. (2022). The latest regulatory changes for pharma supply chains. Pharma Logistics IQ.
https://www.pharmalogisticsiq.com/supply-chain-and-security/articles/the-latest-regulatory-changes-for-pharma-supply-chains

Yeoh, P. (2017). Regulatory issues in blockchain technology. Journal of Financial Regulation, 25(2), 1358-1988. doi:10.1108/JFRC-08-2016-0068
https://www.emerald.com/insight/content/doi/10.1108/JFRC-08-2016-0068/full/pdf

Gathering, G. I. (Director). (2021). Exploring Critical Making | Garnet Hertz [Motion Picture].
https://www.youtube.com/watch?v=h40QgLnEccw

Schulz, L. (Director). (2017). The Three Paradigms of HCI [Motion Picture].
https://vimeo.com/199261220

Haiken, M. (n.d.). 7 Most Common Counterfeit Drugs. Safe Medicines.
https://www.safemedicines.org/2012/08/7-most-frequently-counterfeited-medicines-are-scary462.html

Miller, G., & Duggan, E. (n.d.). Optimizing your data for the reimagined drug supply chain. Fierce Pharma.
https://www.fiercepharma.com/special-report/top-counterfeit-drugs-report#:~:text=The%20erectile%2Ddysfunction%20treatments%20Viagra,teams%20to%20track%20down%20counterfeiters.

White, C. M. (2022). Dangerous Counterfeit Drugs are Putting Millions at Risk, a New Study Says. University Of Connectlcut.
https://today.uconn.edu/2022/06/dangerous-counterfeit-drugs-are-putting-millions-at-risk-a-new-study-says/