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BLOCKCHAIN APPLICATION TO THE PHARMACEUTICAL SUPPLY CHAIN

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ABSTRACT

As supply chains are becoming increasingly more complex, there are always new ways to advance them for efficiency, especially as technology evolves and expands. Blockchain is an emerging technology that has many potential applications to the supply chain, namely, the pharmaceutical supply chain. This thesis examines the current pharmaceutical supply chain from both payment and product standpoints. It explains blockchain technology and provides applications for meeting regulation compliance, creating efficiency for the complex payment system, and providing better treatment for consumers of the products by utilizing the supply chain. This thesis concludes by highlighting the benefits of blockchain application. While it concludes that it is ultimately beneficial to invest in blockchain solutions, it does comment on the overarching challenges it would take to implement them, as many of the applications face similar challenges. The thesis recommends implementing a blockchain system as a means to create efficiency and cut costs due to administrative tasks and slow lag time, as well as create a more secure and interoperable way to store data. However, it notes that due to the relative novelty of the technology, there are many hurdles that must be overcome, namely creating an industry standard, getting all parties to adopt the technology, and cost, that can be overcome if the industry works together to solve them.

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Chapter 1

Introduction

The pharmaceutical industry is often characterized as one with high drug prices and minimal transparency to consumers. Additionally, the industry is comprised of an immense number of key players. These key players are involved in the overall supply chain of the drugs provided to patients, including manufacturing, distribution, and even financial coverage. Unlike other industries where products are not a necessity, life-saving or life augmenting drugs are often essential for consumers, despite high drug prices that vary depending on coverage and location. Additionally, the pharmaceutical industry is susceptible to counterfeit and corruption, especially on a global scale. Given the nature and use of prescription drugs, tampering with drugs can lead to life-threatening and fatal outcomes. The problems listed above can lead to consumer distrust and frustration with the pharmaceutical supply chain and industry as a whole. A lack of coordination within the industry only augments these problems. While there is some communication between entities in the pharmaceutical supply chain, it is not comprehensive enough to provide both assurance from counterfeit and a guarantee of effective, affordable, and available drugs.

Current industry standards may lead to inter-entity security and communication along the supply chain, but there is currently no system set in place for network-wide communication and tracking of prescription drugs. In November of 2013, the United States Congress enacted the Drug Supply Chain Security Act (DSCSA). This law was established to require the pharmaceutical industry to develop an electronic, interoperable system designed to encompass track and trace capabilities of prescription drugs by 2023. The law sets milestones for implementation with the

hope that these target deadlines will ensure full adoption in 2023. Although the law was written with this functionality in mind, there were never clear strategies outlined or mandated for implementation. It was left to industry to decide how to tackle this challenge, and thus, blockchain became a potential solution.

Blockchain is a decentralized storage unit that is known for its immutable ledger and real-time tracking. Blockchain can be used to digitally share and track assets across a network. All of the information on a blockchain is stored in blocks, and each block is confirmed by a digital signature built from the previous block. To change the block, a significant amount of computational power is required, leaving it almost impossible to hack. Each block is stored on nodes that make up the blockchain network. Each entity in the network uses a node, so no one node is critical to the whole system. Given these traits, blockchain serves as a reliable and secure way to track and trace drugs that could be adopted by the pharmaceutical industry to meet the DSCSA requirements. In addition to its secure track and trace capabilities, blockchain can also provide a plethora of other benefits to the industry and its consumers, which will be examined further in this thesis.

This thesis seeks to examine the overall application of blockchain to the pharmaceutical supply chain. As blockchain is an emerging technology, this thesis will provide a comprehensive explanation of the technology as a whole and its relevant features. The pharmaceutical industry supply chain and the guidelines of DSCSA will also be provided as background information. An analysis will then be performed regarding blockchain's benefits as the solution for DSCSA. Later, the additional benefits of blockchain will be explored including how it can be used as a way to manage chargebacks and as a management system for Outcome-Based Reimbursement (OBR). The thesis will also examine the challenges and limitations posed by the novelty and complexity

of blockchain technology and will conclude with an overall risk and benefit assessment of the implementation of blockchain to the pharmaceutical industry.

METHODOLOGY

As blockchain is a fairly new and complex technology, most of the research for this thesis was gleaned from interviews with industry experts. Interviews were held to discuss blockchain for DSCSA and also how it will impact the pharmaceutical supply chain and payment system as a whole. Interviews were conducted with professionals that work for manufacturers, wholesalers, retailers, consultants in the field, and blockchain experts. This mix of professionals helped to create a clear picture of the industry and where it is headed in the blockchain space. Additional research was also conducted using internet articles, podcasts, and videos to gain background on DSCSA, blockchain, and the pharmaceutical supply chain in its entirety.

Chapter 2

Background

THE PHARMACEUTICAL SUPPLY CHAIN

The pharmaceutical supply chain in America is very complex in both the manufacturing and movement of drugs and the flow of money and services. There are many key stakeholders in the pharmaceutical supply chain. These include manufacturers, payers, pharmacy benefit managers (PBM), wholesale distributors, pharmacies, and patients. Each of these players has a specific role. Money and product are transferred between them throughout the supply chain. This section aims to establish the roles of each of these entities and show their crossover and complexity within the drug supply chain. Table 1 below defines the role of each of the key players.

Table 1: Role of the Key Players in the Pharmaceutical Supply Chain

Entity	Role
Manufacturer	• Research and Development of drugs • Produce drugs
Payers	• Pay for drugs; typically the insurance companies
PBM	• Negotiate prices of drugs with manufacturers on behalf of the payers
Wholesale Distributors	• Buy drugs in bulk from pharmaceutical manufacturers • Distribute drugs to pharmacies
Pharmacies	• Buy drugs from distributors and sell to patients
Patients	• The end user of the pharmaceutical product

Manufacturers are the entity within the supply chain that develop and produce drugs. A branded drug manufacturer is responsible for researching and developing the products they sell.

Generic drug manufacturers do not develop new drugs. Instead, they manufacture a generic compound that is off patent from its branded competitor. In 2004, the ten biggest pharmaceutical companies made up sixty percent of U.S. drug sales. (Health Strategies Consultancy, 2005). In order to produce a drug, many steps must be taken. The steps for creating a tablet are highlighted in Figure 1 below. These steps may require outside suppliers to provide materials. For example, there may be an outside company that creates the packaging labels or provides bulk Active Pharmaceutical Ingredients (API). In order to secure the supply chain and ensure that all of the product is suitable for sale, specific information is stored regarding quality and authenticity. This information includes the provider information for raw materials, testing data that confirms correct material after purchase, license to manufacture, demand, manufacturing orders, quality assurance (QA) of the formulated drug, and the temperature throughout the process according to Linda Puili, an executive at Merck Pharmaceuticals (Puili, 2005).
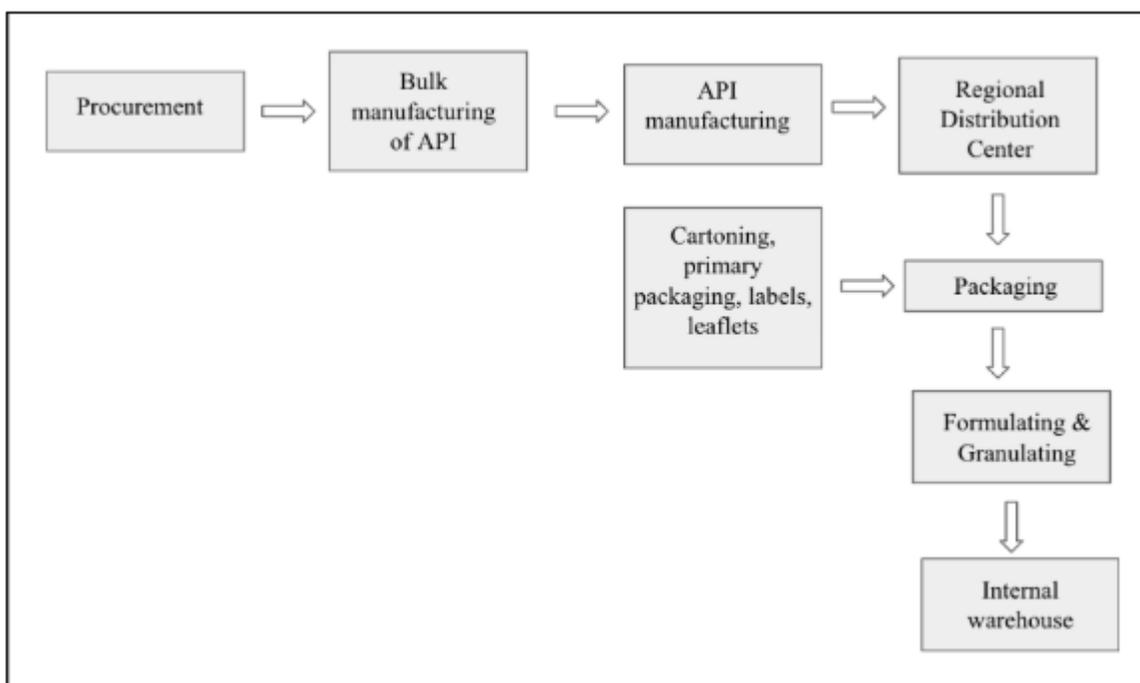
Figure 1: Manufacturing a Tablet

The main role of the manufacturer lies with production, but it also interfaces with many of the other key players regarding sales of the product. Manufacturers sell directly to the wholesalers. Sometimes the manufacturers will also sell directly to a retail pharmacy, a mail order pharmacy, a specialty pharmacy, a hospital chain, or a health plan. They determine demand and prove the value of their product via clinical trials. Using an algorithm that factors in demand, competition, and marketing costs, they determine the Wholesale Acquisition Price (WAC). The Average Wholesale Price (AWP) is garnered from this. Based on the purchasing power of the distributor, most branded drugs are sold at five to forty percent of the AWP (Health Strategies Consultancy, 2005).

Wholesalers buy the drugs from the manufacturer and distribute them to other entities, namely retail pharmacies, mail-order pharmacies, hospitals, and long-term care pharmacies. They store and warehouse the drugs as a baseline, but they also can repackage drugs, create electronic service orders, help with reimbursements, and partake in drug buyback programs. Due to large amounts of consolidation, there are three main wholesalers: McKesson, Cardinal Health, and AmerisourceBergen. In 2004 they made up eighty-eight percent of the market's $212 billion value (Health Strategies Consultancy, 2005).

Pharmacies are the last step that requires physical movement of drugs before a patient interfaces with it. Pharmacies normally purchase drugs from wholesalers, and they retain physical possession of the drug. Their role is to maintain adequate drug supply, facilitate billing and payment for consumers, and provide safety information to patients. There are a few different types of pharmacies including independent, chain drug store, mail order, pharmacies at supermarkets, etc. There are also specialty pharmacies that handle more complex drugs such as injectables and long-term care pharmacies that contract with nursing homes to supply their residents.

PBM manage fifty-seven percent of prescription drugs in the U.S. (Health Strategies Consultancy, 2005). Their core services and tools are as follows. They make formularies, or lists of drugs that they will cover, to help negotiate drug prices. The manufacturer that can give the highest rebate or discount, gets a higher spot on the formulary, and the patient pays a lower co-pay for that drug. They also create pharmacy networks that allow pharmacies to dispense prescription drugs to their health plan enrollees in exchange for reimbursements and dispensing fees from the pharmacy. They handle claim adjudications, generic and therapeutic substitutions for drugs to get patients to use cheaper generics, and quality focused programs. PBM typically do not touch the drugs unless they also own a mail order or specialty pharmacy.

The movement of drugs is important, but understanding the flow of money and services is significant, as well, and adds to the complexity of the supply chain. The PBM typically provides the greatest amount of service. They act on behalf of their payers to negotiate for discounts on their drugs. The PBM work with the manufacturers and insurers to create a formulary that gives preferred placement, and therefore easier and cheaper access for patients to drugs that are discounted. Insurers provide prescription drug coverage for their customers, and they also pass savings through to PBM.

Money flows back and forth between entities in the supply chain, making it both complicated and inefficient. The patients pay premiums to their insurance company for prescription drug coverage. They also pay a drug copay to their PBM when purchasing drugs. This money is collected at the pharmacy but is given to the PBM. Patients may also receive copay assistance from manufacturers if needed. The pharmacy buys drugs from the wholesaler and gets a percentage from the PBM when they make sales of drugs. The manufacturer may have negotiated a set price for drugs with the pharmacy that is lower than what the wholesaler bought it for. When

this is the case, the wholesaler sells it to the pharmacy at the contracted manufacturer price and requests money back from the manufacturer. This is called a chargeback. Chargebacks can also occur if the manufacturer negotiates a lower price with the PBM. PBM get a cut from every part of the supply chain. They pay pharmacies when drugs are bought, but receive money from patients in the form of copays, manufacturers in the form of rebates, and payers so that the PBM will negotiate for them. The patient never directly pays the manufacturers or pharmacies, and the coverage of their drugs may be determined not by efficiency, but by rebates and formulary placement. Figure 2 demonstrates the full flow of drugs, services, and money in the pharmaceutical supply chain.

	Drugs		Services		Money	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Manufacturer		Wholesaler	PBM: Preferred formulary placement		Wholesaler	PBM: Formulary payments, market share payments, performance incentives, rebates Patient: Copay assistance
Payer			PBM: Managed drug benefits	Patient: Prescription drug benefits	PBM: Share of manufacturer rebates	PBM: Negotiated payment
Wholesaler	Manufacturer	Pharmacy			Pharmacy	Manufacturer
PBM				Payer: Managed drug benefits Manufacturer: Preferred formulary placement	Patient: Copay Manufacturer: Formulary payments, market share payments, performance incentives, rebates Payer: Negotiated payment	Pharmacy: Negotiated payment Payer: Share of manufacturer rebates
Pharmacy	Wholesaler	Patient			PBM: Negotiated payment	Wholesaler
Patient	Pharmacy		Payer: Prescription drug coverage		Manufacturer: Copay assistance	PBM: Copay Payer: Insurance premium

Figure 2: Flow of Drugs, Services, and Money in the Pharmaceutical Supply Chain

WHAT IS BLOCKCHAIN?

In 2008, blockchain was first utilized as the cryptocurrency bitcoin. Satoshi Nakamoto was the creator of bitcoin, which utilized blockchain as its underlying technology. Bitcoin's popularity

sparked a surge in cryptocurrency usage and inspired technologists to shift their attention to blockchain itself. Since then, many applications of blockchain have been identified, and proof of concepts have arisen to help determine feasibility and applicability. Blockchain utilizes key technology principles such as cryptography, decentralization, and immutability while honing in on a peer to peer interactions that eliminate middlemen. Blockchain proves useful for supply chain networks and has properties such as smart contract capability, real-time tracking, and ability to function as a public or private network with all of which having the potential to create greater efficiency and transparency in the supply chain.

BLOCKCHAIN TECHNOLOGY

In order to understand how the blockchain can be utilized in a supply chain, it is important to understand what it is and how it works. The blockchain is essentially a shared, decentralized, immutable database that grows as records are added. It can help eliminate the middleman by creating trust on a peer to peer level. The records that are collected and stored on a blockchain are secured with cryptography to ensure the records are secure.

Cryptography is one of the most important aspects of blockchain technology. It is used in a blockchain to protect user identities and information, secure blocks and transactions, ensure confidentiality, and maintain data integrity. It is used to disguise and reveal information using complex mathematical algorithms called ciphers. Plaintext, such as a text message or a computer program, can be encrypted using these ciphers. This produces a ciphertext which can be given to a recipient and decrypted with a decryption algorithm to reveal the plaintext. There are two types of cryptography:1) symmetric cryptography, also referred to as private key cryptography, uses the

same key for encryption and decryption and utilizes a secure distribution channel to share this key; 2) asymmetric key cryptography, or public key cryptography, utilizes symmetric cryptography. It uses a public key to encrypt and a private key to decrypt. It does this by allowing senders to access someone's public key to send them a message. Public keys can be shared with anyone and cannot be used to identify the private key. Once the sender uses the public key, the message can only be viewed when the receiver opens it with their private key. Private keys should never be shared. This process is exhibited in Figure 3 below. Public key cryptography eliminates the need for a secure key distribution channel because there are different keys for encryption and decryption. It also authenticates the identity of senders and receivers. This is the technology that encrypts blockchains.

Figure 3: Asymmetric Encryption Model
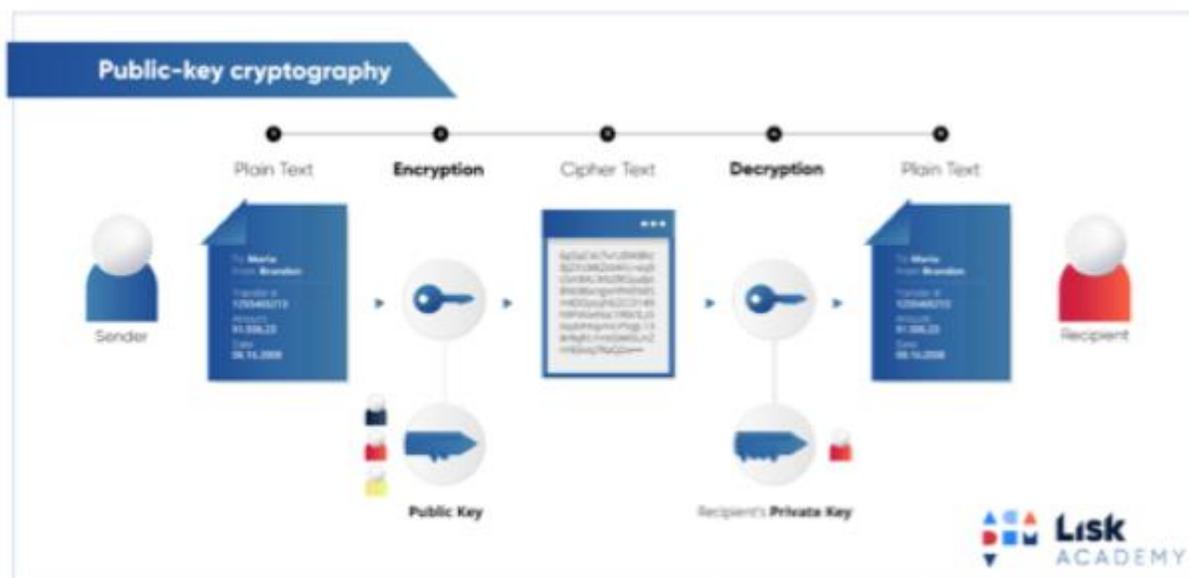
Blockchain functions as a decentralized ledger that is secured by cryptography. While different types of blockchains may have different degrees of decentralization, typically decentralization means that there are no central third parties involved, such as a bank, that acts as a trusted middleman to create legitimacy. Instead, it relies on peer to peer interactions between the

whole network to verify transactions. Thus, no single entity controls the transactions and information in the blockchain. Instead, it is governed by all entities in the network. In order to do that, it utilizes a continuously growing list of records. These records are called blocks. All of the blocks are verified by cryptography, thus eliminating the need for a third party to authenticate transactions and create legitimacy. All of these blocks are stored in the ledger, and the ledger is stored on all the nodes in the network. Nodes are copies of the blockchain ledgers and protocols that are stored on computers or hardware devices in the blockchain network. The decentralization of information on the nodes allows all parties to have all transaction information and protocols. Each network on the node acts as both the client and the server. One of the biggest advantages to this is that information is more difficult to lose compared to a centralized database. Since data is stored on multiple nodes, if one is damaged, nothing is lost.

Immutability is another characteristic of a blockchain. All blockchains consist of data sets that are made of data. This data is called a block. Every time a block is added, the blockchain is extended to make up the complete ledger of transactions. Blocks are time stamped, validated by cryptography, and given a hash value. The hash is generated using the previous block and a nonce, or a random number for verifying the hash. Hash's are unique to each block, helping prevent fraud. Figure 4 below shows visually how the hash is formed. To add the block to the chain, it must be validated by a majority of nodes in the network. The nodes must agree on a transaction based on a set consensus mechanism that validates the transaction in a block and on the chain. This consensus mechanism can be defined as, "the process in which a majority (or in some cases all) of network validators come to an agreement on the state of a ledger. It is a set of rules and procedures that allow maintaining a coherent set of facts between multiple participating nodes" (Nofer, 2018). That being said, the new blocks are not automatically added to the ledger.

It must first pass the consensus mechanism. In a public ledger, such as bitcoin, there are miners who use high powered computers to verify transactions. They are rewarded with bitcoin. This is known as proof of work. Other methods of consensus exist, as well and will be explored later in this thesis. This is a key part of the blockchain because once something is added to the ledger, it cannot be removed, and thus the validation to ensure blocks are correct. Blockchains are append-only databases, meaning data can be added but not changed. Hence, a truly immutable ledger is achieved. This is significant because it holds users accountable for the data they enter if manual entry is used. This also helps ensure accuracy and prevents data corruption.
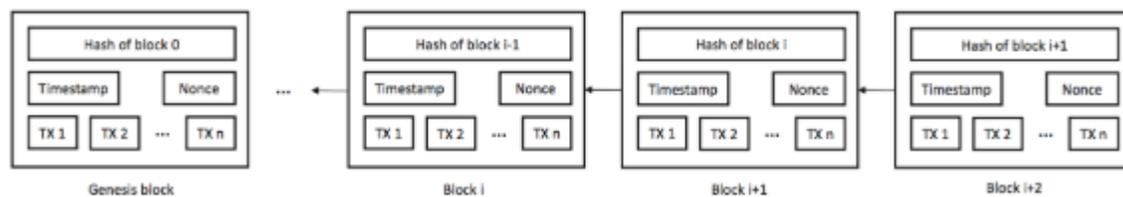
Figure 4: Blockchain Hash Generation

BLOCKCHAIN FUNCTIONALITY

Blockchain has key characteristics that are especially applicable to supply chain systems and will be explained further. These include its ability to track in real time, its ability to function as a private or a public ledger, and its use of smart contracts. While there are definitely other aspects of a blockchain that may be worth exploring, they will not be included in the scope of this thesis.

In order to understand how blockchains can be applied to a supply chain, it is important to differentiate between private and public blockchains. Both of these types of blockchains are decentralized, P2P, append-only databases that maintain copies of the ledgers on all nodes. They

also both require a consensus mechanism in their protocol. The main difference in the two types of blockchains are the participants in the network. Public blockchains, like bitcoin, are open source and available for anyone to join. This type of blockchain also typically uses a consensus mechanism, like proof of work, that incentivizes participation in the network. This type of ledger requires significant computational power and allows for complete transaction transparency to everyone. This is not favorable for most businesses. That is why businesses may use private or permissioned blockchains. These networks require an invitation that is validated by the entire network or the rules in place by the network. This means that the information is not open to the public, and restrictions can be made regarding who can see what in the network. They also employ less energy as they do not require as complex consensus mechanisms as proof of work. Another added feature that can help safeguard identify and transaction information on blockchain is zero knowledge proof. It is an added layer to the blockchain that uses mathematics to send a transaction proving the person sending it is who that say they are without disclosing the full information. This can be added to a permissioned ledger to help maintain further anonymity.

Smart contracts are essentially automated contracts that live on the blockchain and trigger transactions when certain conditions are met. They were originally designed for the P2P exchange of money only. However, the Ethereum project worked to decouple it from the blockchain layer of the protocol, and use it for value transactions, as well. The smart contract is a code that runs on top of the blockchain network. They work similarly to legal contracts, but may not have the same legality. The involved parties simply define rules, and the smart contract will execute them automatically as applicable. The goal of this is to cut costs for transactions and provide more security and reliability. They can be used for money exchange, ownership exchange, governing, etc. Because they are used by a blockchain, once the code is embedded they become available to

the whole network and are tamper and revision resistant. All of the transactions are also recorded in the blockchain ledger, creating a transaction history. This may help speed up transactions, create trust, and eliminate intermediaries like lawyers and banks. Because smart contracts automate many processes, it may speed up the flow of information. If there is no manual input needed for information to be shared, it can become visible at a faster rate than manual methods. This is especially true if the Internet of Things (IoT) technology is used to collect data. This concept will be explored later in this thesis.

THE DRUG SUPPLY CHAIN SECURITY ACT

The bridge between the pharmaceutical supply chain and blockchain is the Drug Supply Chain Security Act (DSCSA). This thesis will examine the link between the two in the next chapter, but before that can be done, it is important to understand what DSCSA is. DSCSA is Title II of the Drug Quality and Security Act of 2013. It was signed into law on November 27, 2013, by President Barack Obama. The premise of the law is that it outlines the necessary steps to create an electronic, interoperable system that can be used to track and trace prescription drugs that are distributed in the United States. DSCSA was established to replace the fifty state piecemeal of pedigree requirements regarding track and trace capabilities of prescription drugs in the pharmaceutical supply chain (Reed, 2014). It is a very relevant track and trace law but is not the only one of its kind. Over forty countries worldwide have implemented track and trace laws including the European Union (Bonnstetter, 2018). However, for the sake of this thesis, DSCSA will be the main focus for track and trace legislation.

DSCSA establishes some key definitions regarding the supply chain and its components. Namely, it defines the different players in the supply chain. A manufacturer is defined as an entity with an application under section 505 or a license from section 351 of the Public Health Service Act. It can also be the entity that manufactured the product if it is not the one with the license or application. The wholesale distributor is an entity that is involved in the distribution of prescription drugs to an entity that is not a patient. A dispenser is a retail pharmacy, hospital pharmacy, chain pharmacies, or others that are legally eligible to distribute prescription drugs that are not wholesale distributors (Zenk, 2015). Definitions were also established for the suspect and illegitimate drugs. Suspect drugs are those that have elicited a reason to believe they may be counterfeit, fraudulent, adulterated, or otherwise unfit for distribution because they may pose a serious health threat. An illegitimate drug is one where there is credible evidence for one of the above issues (Bernstein, 2014). These definitions are important in understanding the main elements of the law.

The law establishes a variety of key provisions that need to be implemented in stages for full implementation of a fully electronic, interoperable system in 2023, ten years after the initial implementation of the law. The key provisions of the new law apply to manufacturers, re-packagers, wholesalers, dispensers, and third-party logistics (3PL) providers. The provisions are as follows: product identification, product tracing, product verification, detection and response, notification, and wholesaler and 3PL licensing. For the product identification provision, the manufacturers and re-packagers are required to use a unique product identifier for their prescription drug packages. Product tracing requires that manufacturers, wholesale distributors, re-packagers, and many dispensers provide information regarding drug handling when it is sold in markets in the United States. Product verification requires the same key players as before to establish a system for verifying product identifiers on most prescription drugs. Detection and

response refer to creating a mechanism to investigate and quarantine drugs if they are suspect or illegitimate. Notification is the follow up to the FDA and other key stakeholders if those drugs are indeed illegitimate or suspect. Lastly, wholesalers and 3PL are required to maintain and report and maintain their licensing with the FDA. The FDA creates a database for this and a set of standards ("Drug Supply Chain Security Act - Key Provisions of the Drug Supply Chain Security Act.", 2017).

As mentioned, the DSCSA requirements will be fully implemented by 2023. The end result is set to be able to verify identifiers of the drug at the package level, improve efficiency in regard to recalls, facilitate the electronic exchange of transaction information for each sale of a drug, and develop a prompt response to suspect and illegitimate drugs (Bernstein, 2014). In the meantime, the law was implemented in stages to prepare for the full implementation. Figure 5 below shows the timeline of DSCA requirements and which entity is responsible for meeting the deadlines. The FDA did not establish one definitive way to meet these requirements, but blockchain has been adopted and tested in PoC with many leaders in the industry. This will be explained and explored in the next chapter.

FEDERAL IMPLEMENTATION TIMELINE

SUPPLY CHAIN MILESTONES

NOVEMBER 27, 2013
Congress enacts the Drug
Supply Chain Security Act

JANUARY 1, 2015
Manufacturers send and
distributors receive TI/TH/TS +
begin direct purchased statement

Suspect and Illegitimate Product
Requirements Effective

NOVEMBER 27, 2017
Manufacturers serialize product

NOVEMBER 27, 2018
Repackagers serialize product

NOVEMBER 27, 2019
Distributor traceability

NOVEMBER 27, 2020
Dispenser traceability

NOVEMBER 27, 2023
Unit-level traceability

2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024

FDA MILESTONES

NOVEMBER 27, 2017
Federal distributor licensure regulations effective

NOVEMBER 27, 2015
National standards for wholesaler distribution licensure anticipated
National standards issued for 3PLs
Waiver guidance issued for exchange of TI/TH/TS
Standards issued for exceptions to product identifier requirements
Standards issued for grandfathering product

MAY 1, 2015
TI/TH/TS enforcement discretion ends

JANUARY 1, 2015
Wholesale distribution licensure reporting begins
Publicly available database of wholesale distributors established by FDA

NOVEMBER 27, 2014
Standards published for TI/TH/TS
3PL licensure reporting begins

MAY 26, 2014
Draft guidance on suspect product and terminating notification

KEY

TI – Transaction Information

TH – Transaction History
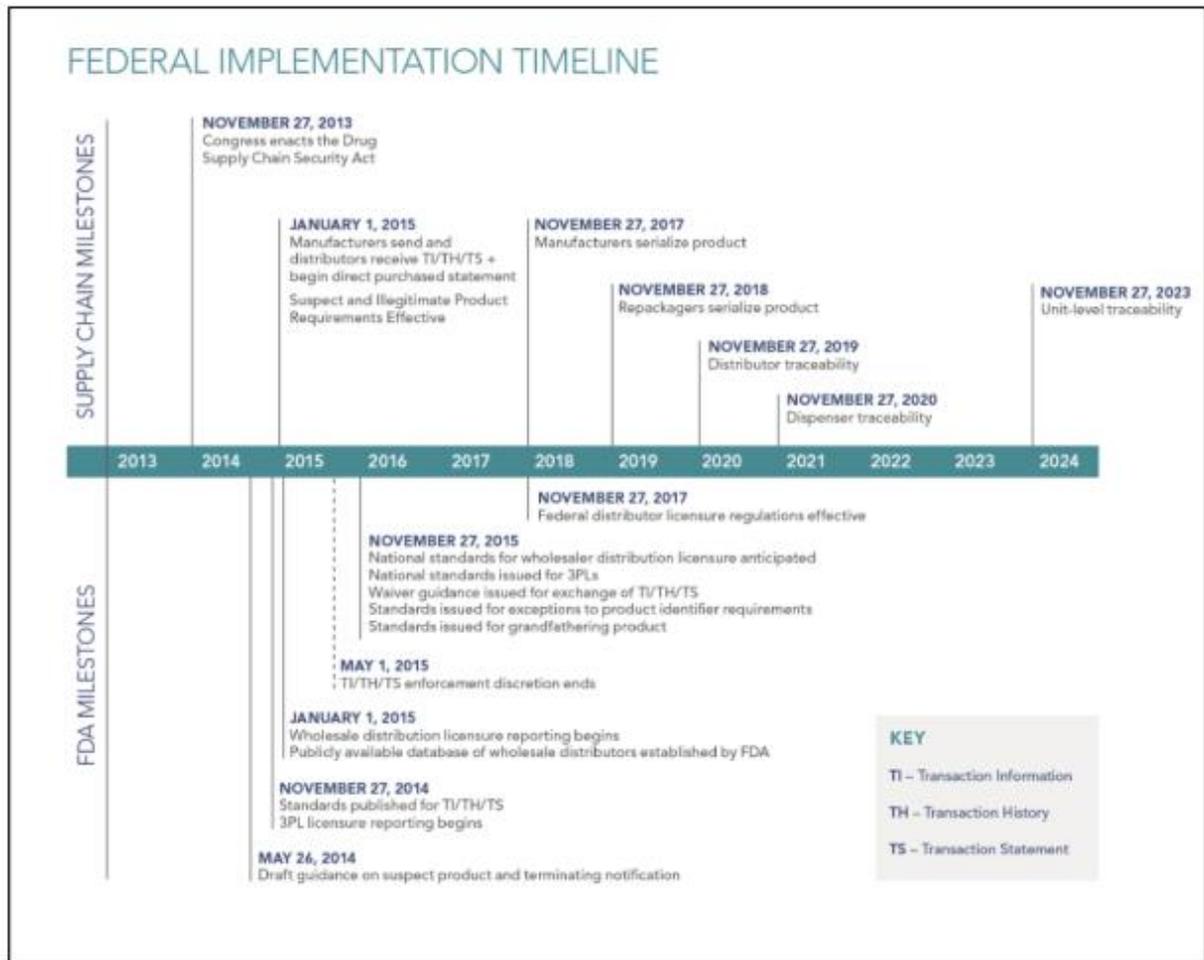
TS – Transaction Statement

Figure 5: DSCSA Requirement Timeline for Implementation

Chapter 3

Blockchain for the Drug Supply Chain Security Act

The Drug Supply Chain Security Act (DSCSA) has been the obvious starting point for the pharmaceutical industry to explore blockchain. As the industry is typically slow to adopt new technology, the law's ambiguity and need for a solution have forced the industry to examine blockchain. At first glance, blockchain has been identified to meet many of the basic requirements of DSCSA and potentially has additional uses that will be discussed in later chapters of this thesis. Because of its adaptability to other areas of the industry, it is worth exploring its uses for DSCSA, as it may have greater value than other systems that are only functional for DSCSA requirements. That being said, it is still imperative to ensure that blockchain can feasibly meet all the DSCSA requirements and overcome the obstacles that plague its implementation. This chapter will look to explore this.

As mentioned, DSCSA requires that all stakeholders in the pharmaceutical supply chain can track and trace their drugs throughout the supply chain to prevent counterfeiting and secure the movement of drugs. It also requires a fully interoperable, electronic system for storage of this data by 2023. Any system used to meet DSCSA requirements must cover the above-mentioned items. As such, solutions have been identified within the industry, and it is necessary to explore them to see how they fare against blockchain. Jeff Stollman, a consultant in the industry, compares the benefits and drawbacks of the proposed DSCSA solutions. These solutions include a relational database, a 1-up 1-down breadcrumb approach, a public blockchain, a private blockchain, and a closed blockchain. The relational database is one in which each database is managed at the

manufacturer level. Each manufacturer would be responsible for the accuracy, reliability, and security of the database which poses difficulties, despite the fact that it is the simplest method. The breadcrumb approach consists of shared transactions between each pair of trading partners. It does not share data with any other party. This is appealing for its practicality, but it falls short because it does not provide enough data security and can be cost prohibitive due to the fact that each trading partner would need to maintain its own database. A public blockchain is not favorable because it is too accessible to parties outside the blockchain since, in its nature, it is available for anyone to see. A private blockchain has a decentralized administration but is questionable as a DSCSA solution due to issues of access and confidentiality. Stollman describes a closed blockchain as being established and governed by all industry players. It would not be visible by trading partners, unlike other popular blockchains, except through fixed report requests. Access to these reports would be determined via the industry governance, presumably only including transactions that the trading partner would need to know. These "need to know" transactions could potentially include information regarding a product that was held or currently is in possession by the trading partner. Likely, upstream visibility on that product would not be included in the "need to know" transactions. Due to these distinctions of a closed blockchain, Stollman identifies it as the best option for meeting DSCSA requirements. It maintains centralized control and meets all potential DSCSA criteria. (Basta, 2017). He also recommends that the blockchain be regularly audited to ensure the integrity of data and system processes. The bottom line for this solution is that it works best if there is a strong governing body with a blockchain system. (Stollman, 2018). Essentially, blockchain is only the best way to meet DSCSA requirements provided it employs proper governance that secures the privacy of data between trading partners. The comparison of the DSCSA solutions can be seen visually in Table 2 below.

Table 2: Comparison of DSCSA Solutions

Basic Requirements Summary

Requirement	1 Relational Database	2 1-Up/1-Down Breadcrumb	3 Public Blockchain	4 Private Blockchain	5 Closed Blockchain
Accuracy	Green	Red	Green	Green	Green
Immutablity	Red	Red	Green	Green	Green
Non-repudiatable	Red	Red	Green	Green	Green
Auditability	Green	Red	?	?	Green
Hack Resistance	Red	Red	Green	Green	Green
Availability	Green	Red	Green	Green	Green
Verification	Green	?	Green	Green	Green
E2E Query	Green	Green	?	Light Green	Green
Confidentiality	Red	Green	Light Green	Green	Green
Access Control	Red	Light Green	Light Green	Green	Green
Cost	Green	Red	Light Green	Green	Green

Blockchain also fares well against the competing solutions due to some of its the key functions. Heather Zenk, an executive at AmerisourceBergen (ABC), one of the three big pharmaceutical wholesalers, wrote that ABC is interested in blockchain technology to meet DSCSA requirements because it can validate the authenticity of a product. It also can employ zero-knowledge proofs to keep all transactions fully encrypted in the blockchain and therefore maintain confidentiality (Zenk, 2018). Since data movement for prescription drugs can be valuable and used as a revenue stream for companies that sell them, it is important to keep some information confidential. Zero-knowledge proofs can help create confidentiality while still allowing for DSCSA compliance and confirmation on the movement of drugs in the supply chain. Zero-knowledge proofs are a type of encryption that works by allowing one party to prove to another party that its statements are true without disclosing any other information (Somerville, 2018). This enables trading partners to share data while still creating business rules that protect confidential information. Smart contracts, also known as DApps depending on the blockchain platform, can

also be promising in aiding with DSCSA because they can enforce business rules like verifying serial numbers without sharing sensitive data. They can help eliminate any administrative work that DSCSA would add to a company because they automatically perform tasks (Somerville, 2018).

While blockchain holds a lot of potentials, it is important to ensure that implementation is feasible. The Center for Supply Chain Studies (C4SCS) employed a study with over fifty companies in the industry to test different blockchain models to determine if they meet all the requirements and can conquer all the difficulties that it faces. For Bob Celeste, the founder of the Center for Supply Chain Studies, blockchain was originally thought to be the best solution for DSCSA because it can facilitate a connection between trading partners all the way back to the manufacturer, a requirement in the 2023 iteration of the law. This is quite difficult with the current landscape given that most entities are only in contact with their adjacent trading partners and do not have contact further down the supply chain. Given that blockchain is a shared network, these relationships would be apparent. It would also provide data immutability and with the use of smart contracts, or DApps, could create a standard for data transfer. This would help alleviate issues with the current system that utilizes EDI messages that are often wrong or time-consuming to manage (Celeste, 2019).

The C4SCS utilized a study to identify potential uses of blockchain for DSCSA. They used reference models based on their hypotheses so they could simulate the data and run the models. The first study they did employed three reference models. Reference Model 1 had the supply chain trading partners provide their transaction information (TI) to a service provider. The service provider then granted access to the blockchain and gleaned the essential data for blockchain storage. DApps were used to process the data and determine if a trading partner could post or

access data on the blockchain. This method required high levels of governance, because all the data was stored on the blockchain, and high operations cost because each stakeholder would be required to retrieve their own EPCIS Event data. They ran this model as a reference knowing it would likely be impractical. Reference Model 2 outlined a system where pointers, or addresses for the transaction information required for DSCSA, would be stored in a blockchain that served as a DSCSA directory. Governance for this model was simple, as all the data was stored off the blockchain. However, a standard for retrieval and storage on each repository would be needed. This system would require multiple steps and would be expensive to locally manage. For the third Reference Model, they tried to highlight a strength of blockchain, namely its use of DApps or smart contracts. Reference Model 3 only stored a few states of the package throughout the supply chain. It did this by utilizing DApps to interpret the EPCIS events and posting the interpretation to the blockchain. ("The Drug Supply Chain Security Act and Blockchain", 2018).

Based on this study, the C4SCS dug deeper for a second study. They examined the models from the first study to find any shortcomings. Reference Model 2 lacked the ability to detect duplicate entries from both counterfeits or mistakes, which defeated the spirit of the law that looked to eliminate counterfeits. Reference Model 3, while originally thought of as a prime contender, showed weaknesses due to the fact that there would never be just one blockchain in such a vast industry and this system would not work if all the data was not stored in one place. The caveat to this is that it could work if there was a blockchain that could also process information from other sources, essentially a truly interoperable system. The second study also used some of the shortcomings from the first study to identify additional options. One of the biggest shortcomings from the original three models was the lack of privacy. Some data is not meant to be shared between all parties, such as their competitors. As blockchain is typically a shared system, this

poses a challenge. The C4SCS identified the use of channels as a potential solution to this. Channels would be established so data in those channels is only shared with members of the channel. It could be posted to the blockchain itself at a later date, but would not be mandatory. They also identified the use of metadata in a data repository and having it available for verification and auditing on the blockchain. However, the issue of privacy is brought up again due to the fact that conclusions about ownership can be drawn from metadata as well. Another shortcoming identified that had originally been proposed as a benefit of blockchain is its immutability. For the case of saleable returns, the seller may not want the new customer to see the previous transaction history, but given that blockchains are immutable, this data cannot be deleted. One potential solution to this was to destroy the key needed to access prior information and essentially create a "forget" system as opposed to a "delete" system for saleable returns (Celeste, 2019).

Given the challenges with blockchain as the main technology solution for DSCSA, Bob Celeste notes that it may be better served in addition to other technologies. He sees it as playing a role in securing the information and as a record keeper for auditing, but essentially storing the majority of the DSCSA information off the block. This would help alleviate privacy concerns because full visibility is not favorable by the industry as a whole (Celeste, 2019). It is evident that blockchain can serve a role in DSCSA, but it may not be the only solution. Further research is needed to completely gage this, however.

Simultaneous to the work of the C4SCS, a company called Chronicled has emerged with the Mediledger project. Mediledger is working with leading players in the industry to create an advanced, customizable decentralized supply chain management system using blockchain principles. The system is working to provide track and trace capability for DSCSA. They are employing an industry-owned permissioned blockchain network with nodes distributed and

operated by industry stakeholders and technology providers. Their approach to data security is to use zero-knowledge proofs. This ensures that sensitive data is only seen by necessary parties, but data can still be verified. This system helps companies to create an immutable record for their transactions, enact business rules while maintaining privacy, protect business intelligence, and connect with the necessary trading partners. They also have a solution for Saleable Returns that was made available in October 2018. This utilizes a combination of look-up directory and verification routing services that facilitate quick communication between the wholesalers and manufacturers for verifying the returns before resale ("MediLedger - Blockchain Solutions for Pharma Companies", 2018). They are leading the industry with blockchain technology.

Blockchain has its benefits, but there are some challenges that face its implementation. The main issue is governance of a blockchain system. Per Nicholas Basta, founder and editor in chief of Pharmaceutical Commerce magazine, no one who is willing to step forward to create this governance, but there cannot be a comprehensive blockchain system without it. Additionally, companies who are complying with DSCSA may not want to step forward with governance, as they would lose their competitive advantage. There is precedence in other industries to create governance systems, such as the financial services industry creating a governing body around the use of credit card transactions (Basta, 2019). However, until then, it will be difficult to fully implement a blockchain system. The research suggests that the governing rules need to include how to handle the security of data. Whether the data be stored off the blockchain, zero-knowledge proofs are used, or a different solution is employed, is still undecided, but it needs to be addressed. Additionally, a blockchain system would need to be fully interoperable with systems not employing blockchain. Other companies such as Tracelink are facilitating non-blockchain based solutions for DSCSA. Given that blockchains need all available data to fully function, it would

need to be completely interoperable with other existing systems. Blockchain has its challenges for tackling DSCSA, but due to the prevalence in the industry and potential for further use, it seems to be a viable option for meeting DSCSA requirements.

The Drug Supply Chain Security Act is a criteria for compliance that greatly shifts the industry and, therefore, needs a capable system to meet those criterion. Blockchain certainly can serve as a means to comply with DSCSA regulation. However, its exact role is still up for debate. From the research, it is evident that it is beneficial for companies to use blockchain in some capacity. This is because DSCSA is a regulatory requirement that does not garner any value add to the company. However, investing in a technology that can only be used for DSCSA would not benefit the companies. Blockchain has value add functions, making its costs to start up and maintain worthwhile. These will be explored in the next two chapters.

Chapter 4

Blockchain for Chargeback Management

From the previous chapter, it is evident that a well-regulated blockchain system would be the best way to meet the requirements of DSCSA. Given its potential to create value for the stakeholders in the industry beyond the regulatory feat, it seems that it is the best investment for these companies. It would help them comply while still saving them money in other ways. This chapter looks to explore a potential value add for blockchain use in the pharmaceutical supply chain, namely, its use for chargeback and rebate management. The pharmaceutical industry has a convoluted payment system as was discussed in the background section of this thesis. This section explores the complexities and offers a comprehensive blockchain solution.

At the most basic level, pharmaceuticals are made by the manufacturer, sold to the wholesaler, and then sold again to pharmacies where patients can purchase them using a combination of their insurance and a potential copay or coinsurance. That being said, payments are not always certain for the manufacturers namely because of chargebacks. There are two common types of chargebacks. The first occurs when a wholesaler buys a drug from a pharmaceutical company and sells it to their customer for a lower contracted price set forth by the pharmaceutical company for that specific customer. Wholesalers and distributors typically purchase drugs at the distributor acquisition price (DAC) or wholesaler acquisition price (WAC). However, most contract prices for their customers are lower than the DAC or WAC. Most of the customers are group purchasing organizations (GPOs) that consist of health systems, hospitals, nursing homes, etc. that negotiate on behalf of their healthcare provider members for the lowest possible contract price (HIDA, 2017). In order for the wholesaler to recoup that loss, they chargeback the difference to the pharmaceutical manufacturers. Most distributors will submit

chargeback requests regularly. Each chargeback typically contains thousands of line items. Per a study on contract standards in the industry put forth by the Health Industry Distributors Association (HIDA), "A typical mid-sized manufacturer will process hundreds of thousands of chargeback requests per year, and transfer hundreds of thousands of dollars per year in chargeback payments" (HIDA, 2017). The second case of chargebacks occurs if a transaction has failed and the drug company must reimburse their customer. Both types of chargebacks often result in a loss for pharmaceutical companies but are necessary to ensure room for error. They tend to cause a loss because of the complexity set forth by managing the inquiries for a chargeback. Typically, chargebacks need to be approved by the manufacturer before they are distributed, but oftentimes the chargebacks only provide the requested amount of money and do not show evidence of the reason for charging back. This leaves ample room for duplicate and unauthorized submissions. While pharmaceutical companies typically prefer chargebacks to be linked to an individual sale, that is not always how they are provided (Lacoma, 2018).

Rebates are another source of complexity in the pharmaceutical payment system. As previously discussed, PBMs negotiate drug prices with the pharmaceutical manufacturers on behalf of the insurance companies to create pharmacy benefits for their customers. Three PBMs dominate seventy percent of the prescription claims in the industry. These three PBMs are Express Scripts, CVS Caremark, and OptumRx of UnitedHealth (PhRMA, 2017). PBMs hold a significant amount of power in the industry, as they create formularies for their clients that influence which medications will be accessible to their patients from a coverage perspective. Manufacturers negotiate rebates with PBMs to ensure better placement on the formulary, and in turn, increased access to their drug for patients. Large PBMs carry significant amounts of leverage because of their dominance in the market. Rebates are normally based on a percentage of the drug list price,

and more rebates may be given when specific thresholds of sales are reached for that product. These rebates are typically paid retroactively, further complicating the flow of drug payment. Manufacturers also pay PBM administrative fees for administrative work related to reimbursements. In addition to their negotiations with manufacturers, PBMs work with health plans and employers. They use them to help get the drug at the lowest prices for their customers. There are two types of contracts the health plan sponsors can employ with PBMs. They can either use spread pricing where the health plan pays the PBM an amount for the drug and the PBM pays the pharmacy some of that amount and retains the rest as its profit. The other is the pass-through, where the health plan pays the PBM an administrative fee and the amount for the drug. They only keep the administrative fee and send the rest to the pharmacy. This is typically seen as more transparent (PhRMA, 2017).

Generally, the chargeback and rebate system work as follows. The PBM or wholesaler will send the request for the rebate or chargeback amount to the manufacturer. The manufacturer then sends back a Chargeback Reconciliation with Resubmittal Response that tells them how much they will be paying. This is normally completed within thirty days of getting the sales data. The Resubmittal Response typically details any errors that the manufacturer finds with the chargeback request for a drug, whether it be that they charged back too much or too little. If the chargeback is found by the manufacturer to have no errors, the payment is submitted. If there are errors, they are normally detailed in the Re-submittal Response. The chargebacks can be debited back in multiple ways. The manufacturer can accept a distributor debt memo, send an electronic credit document, or send an ACH transfer to the distributor via the Chargeback Reconciliation transaction set. Normally they employ one of these methods to reduce paperwork and quickly chargeback the funds. The payment methods can vary, however, based on the manufacturer and their relationship

to the trading partner (HIDA, 2017). Albert Chan, an industry consultant, notes that there are not many errors in the chargeback sphere, and they may only account for as little as two percent of all chargebacks. However, for a company that does several billions of dollars in sales a year, two percent is a vast amount. Additionally, the current system is inefficient because of lag time between ratification and a lack of standardization in drug identification (Chan, 2019). Thus, prompting the need for an increase in efficiency in the system.

Given the amount of movement of money in the payment process, it is evident that the payment system for pharmaceuticals is complex and convoluted. Not only is it hard for companies to manage all of their payments, but also it lacks transparency and efficiency. That is where blockchain may be able to add value. Given that blockchains can employ smart contracts, they would be able to use the contracts for WAC, DAC, GPO purchases of drugs, rebates, and any other contracted payment document in one stream. Utilizing smart contracts and a blockchain network could help create real time tracking, which could mitigate or even eliminate lag time. A blockchain system is an immutable ledger which would help shed light on illegitimate claims and could easily link each claim to the actual transaction. This would be beneficial to the pharmaceutical companies and could help mitigate losses due to chargebacks. The pharmaceutical companies could also benefit from this because it would create more visibility around the places errors are made, and in turn, they would be able to prevent them from happening (Yeh, 2019). Ultimately, in the same way that blockchain benefits DSCSA compliance, blockchain can benefit this use case. It would increase operational efficiency by creating a clear ledger of products, lower administrative burden by automating chargeback and rebate reconciliation, and take inefficiency out of the supply chain. This would benefit all stakeholders, and if savings are made, could even be transferred down to

the end consumer. It could also help create more predictable drug pricing, as the data regarding its overall pricing would be available on the blockchain network for quick retrieval (Yeh, 2019).

A standard governance would be needed in order for a blockchain to operate. Because of this, all transactions would be verified through the standard governance that pulls from the established contracts to help streamline the process, eliminate errors, and link each chargeback to a transaction without any back and forth between industry players. Smart contracts would help with automation and reconciliation of payment and claims. Instead of sending information back and forth between the trading partners, whether it be the manufacturer and the distributor or the health plan sponsor and the PBM, it could all be streamlined in one place. This would eliminate the need for a third party to verify the information or people within a company to verify it, saving both time and resources. The use of governance would also help standardize the identification of drugs, as it would be uniform throughout the system. Payments could be sent instantaneously based on the agreed-upon parameters with minimal lag time. It could use real-time information about payments and sales to verify chargebacks and rebates and immediately transact them to the appropriate parties.

Stakeholders may not want to share contracts with all their trading partners, but a smart contract on a blockchain network could allow for aggregation of them into one place without the need for human viewing. Just as privacy was an issue for DSCSA trade information, the same prevails for this. Whichever method for protecting sensitive data is agreed upon for the DSCSA implementation of blockchain could be employed for this. Whether it be storing specific criteria off the block, utilizing zero-knowledge proofs, or creating channels within the blockchain that would only be used for specific trading partners, it would foster an environment where smart contracts could streamline the process safely. Ultimately, the same way that blockchain benefits

DSCSA compliance can be applied to this use case. It would ultimately increase operational efficiency, lower administrative burden, and take inefficiency out of the supply chain. It could also help create more predictable drug pricing, as the data regarding its overall pricing would be available on the blockchain network for quick retrieval (Yeh, 2019).

In order to enact the benefits of a blockchain, it is important to implement a feasible system. Brian Yeh, an industry consultant, notes that the system would need to have input from all the major players in the value chain, namely, the pharmaceutical manufacturers, the wholesalers, the PBMs, insurers, and any other entity that holds a stake in reimbursement. A blockchain would work best if it was interoperable across multiple languages and could integrate data from non-blockchain systems, just as for DSCSA. This would be important as the pharmaceutical companies could still use systems to manage inventory, revenue, pricing, and any other necessary data off the blocks. A governance system is also needed, just as for DSCSA, that would specify what is available to the blockchain network and who would manage the data. It would be helpful to use a language that is good at processing smart contracts, such as Ethereum. A private chain would be needed to secure the data from the public, and a system for managing secure data, such as zero-knowledge proof would need to be identified (Yeh, 2019). A blockchain system for chargebacks and rebates may need to be created independently from that of DSCSA, as not all stakeholders are involved and the blockchain may not be able to process all the transactions for DSCSA and chargebacks and rebates. However, once one system is established, governed, and agreed upon by key stakeholders for DSCSA, it will be easier to facilitate a conjunctive one for this use case.

Some of the biggest hurdles facing blockchain implementation for chargeback and rebate management are the same as those for DSCSA. However, there are some niche hurdles that a blockchain for chargeback and rebate management would face. One of the main challenges is that

it would need to seamlessly integrate legacy systems that store the data needed for these transactions (Yeh, 2019). This would be solved if a blockchain network was established that could interface with non-blockchain systems. It would be the responsibility of the service providers to create connections between the types of systems to enable data transfer. Another hurdle would be determining which supply chain entities are necessary to be on and utilizing the blockchain. It would seem intuitive that just the main players in chargebacks and rebates would be needed, such as the manufacturer and wholesalers, but it is important that all entities that touch payment for drugs are included. This may be the most difficult feat especially as it makes its way down the supply chain to smaller entities like hospitals and pharmacies. Bigger companies that may benefit from a blockchain by reducing administrative costs may not want to foot the bill for smaller entities who may not glean as much value by investing in a blockchain system. This may cause problems, as it will be difficult to begin implementation and testing without full buy in and startup finances (Chan, 2019). For now, it is not as critical to form the whole network of stakeholders as it is for DSCSA as it is not an issue of compliance and transactions can be validated between the entities on the blockchain even if there are necessary steps off the blockchain. This could still decrease the time and administrative costs spent on ratifying chargebacks and on negligent errors.

Using a blockchain network for chargeback and rebate management is just another use that may provide efficiency to the pharmaceutical supply chain. Its use to eliminate errors and streamline the chargeback and rebate system via smart contracts and real time tracking on the ledger would not only save time, but also could save the companies money for their bottom line due to reduced administration costs and quicker and more accurate reimbursements. When governance is established for this entity it will allow all players to better standardize their product IDs and facilitate trust and agreement within the industry. While these are the most relevant

advantages to blockchain for chargeback and rebate management, there are also additional benefits that may come in the future as blockchain becomes more mainstream. While outside of the scope of this thesis, it is important to add that blockchain may be beneficial for payment transparency regarding chargebacks and rebates, and depending how the governance is established, could even empower the consumer to have more transparency regarding their prescription drug costs. Additionally, it is possible that in the future a blockchain system could facilitate the use of cryptocurrency in the form of a stable coin to transact chargebacks and rebates, and would be similar to the lines of credit already established now.

Chapter 5

Value Based Care Management Using Blockchain

Through this thesis, it has become evident that blockchain can aid the key players of the pharmaceutical supply chain in complying with regulatory requirements while adding value to their current practices. This chapter looks to explore another area of business that blockchain may assist, and will show how it may even have a trickle-down effect for patients' access to expensive prescription drugs. Currently, the healthcare system focuses on a fee for service approach (FFS). This means that patients pay for a service or drug no matter the outcome of their health condition. Due to the exorbitant cost of healthcare spending, namely the cost of prescription drugs for the purposes of this thesis, many are looking to other alternatives to this payment system, as high costs can sometimes lead to lack of accessibility to lifesaving drugs. The thought is that shifting from a volume-based system to a value-based system could cut costs and increase patient access, as payment would only be provided for effective outcomes. This is known as an outcome-based reimbursement (OBR). However, some difficulties facing this method are administration fees, logistics, and execution. Blockchain may be able to serve as a solution in this regard, as it can provide automation, security, and ease of maintenance using its key properties. It can also help safeguard information, and these features will be explored in this chapter.

As mentioned, drug prices are burdensomely high for consumers. In 2015, drug spending reached $329 billion, or about $1032 per capita, with thirty percent of the total amount spent on prescription drugs being spent on one percent of all available drugs (Zui, 2018). The current system most commonly uses the FFS model that encourages a volume driven focus instead of one that is

value based. This means that payments are issued for all the services and drugs provided even if they are not effective at curing the patient (Miller, 2009). This is especially true for drugs, and due to high prices, could lead to a lack of coverage by insurers. Many drugs that have high prices are risky for insurance companies to cover. This is because there is no guarantee that the drug will work. While they may prove effective in a clinical environment where all subjects must meet eligibility criteria to partake in the study and are closely monitored to ensure proper adherence to the drug regimen, most consumers may be taking the drug with other medication and may not adhere as strictly to the protocol. This does not make it favorable for insurance companies to cover the drug, and therefore, those drugs may not be included in their formulary. The cost of coverage may not be worth the risk of lackluster effects that would require the insurers to pay for additional treatment (Zui, 2018). The risk aversion by insurance companies may lead to negative health outcomes for the patients who rely on their coverage, as they will not be able to afford some drugs without the assistance of their insurer. Because of this, OBR has been explored to see if it would lower drug prices and increase coverage for patients.

The basis of OBR is that the insurance company would only pay in full for the drug if the drug was effective for their patients. This shifts the risk from the insurer to the drug manufacturer, as their product must be effective to receive the full reimbursement for its purchase. This may seem unfavorable to the manufacturer, but given the fact that the insurers work with their PBM to create formularies, this may actually be more beneficial for the drug manufacturers. If a drug is high on a formulary or not included at all, the manufacturer is not able to make a profit at all on their medications because patients will not have access to them. This would effectively lower their revenue. If the manufacturer works with the insurers and PBM to ensure placement on the formulary and coverage of their drug in exchange for participation in an OBR payment system it

would be beneficial for all parties, including the patient, as they would have access and potentially

lower out of pocket costs for a wider range of potentially life-saving drugs. Table 3 (reproduced

from Table 1 in Xu, et al. 2019) shows OBR payment systems currently in effect in the U.S. to

show how guidelines are made for payment.

Table 3: OBR Arrangements in the US between Manufacturers and Insurers

Year	Drug	Mfg	Insurer	OBR Arrangements
2009	Junuvia & Janumet	Merck	Cigna	Merck refunds what insurer pays for Junuvia & Janumet according to how well diabetes patients are able to control their blood sugar.
2016	Repatha	Amgen	Cigna, Harvard Pilgrim	Amgen refunds insurer if patients do not reduce their LDL-C level by at least the amount shown in clinical trials (FiercePharma 2016a)
2016	Trulicity	Eli Lilly	Harvard Pilgrim	Eli Lilly refunds insurer if patients do not lower their blood sugar to a target amount; in exchange, insurer places Trulicity on its formulary with relatively low co-payment (FiercePharma 2016b)
2017	Kymriah	Novartis	CMS	CMS only reimburses Novartis if patients with pediatric leukemia respond to the drug (Fortune 2017)

Before an OBR system can be implemented, it is important to understand the situations it

would serve best. Per a study on OBR by Liang Xu, et. al., OBR is not necessary for all drugs and

insurers, and may not be any more cost effective or accessible than the current system. The amount

of risk an insurance company is willing to take on correlates to the effectiveness of OBR. Namely,

a risk-neutral or risk-taking insurer would not see a difference if they used OBR. However, a risk-

averse insurer would be able to leverage OBR to create access to a wider array of drugs. Drug

manufacturers would also increase profit when employing OBR with risk-averse insurers as the

current system would likely require a prohibitively high rebate in order for the insurer to provide

coverage. In addition to insurer risk behavior's link to OBR effectiveness, this study showed that

when there are many alternative drugs, OBR can be less effective and in order to effectively create

more access to newer more expensive drugs, prior authorization would need to be used conjunctively with OBR. Overall, the study showed that when OBR is used with the right insurers, manufacturers, and drugs, it can potentially shift risk off the insurer which effectively increases coverage. It can also positively impact manufacturer revenue as increased access means more drug sales (Zui, 2018). This creates major problems in the execution of this payment system, as there would need to be multiple types of reimbursement systems in place with the manufacturers and insurers. There could potentially be an insurer and manufacturer pair that employ different payment methods for different drugs in the manufacturer's portfolio, creating more complexity in an already complex payment system. It would not be worthwhile to implement a system that cannot be maintained or that requires so many administration fees that it outweighs the potential savings or increases in revenue. Additionally, in order to utilize OBR, the insurers would need access to patient data to validate the effectiveness of the drugs they covered. With the current systems available and the current regulatory system, this would pose as difficult. That is where blockchain may provide benefit.

Just as in the previous two use cases, blockchain can help provide interoperability, ease in implementation, and security and compliance to the OBR payment model for the pharmaceutical supply chain. One of the key elements to this application of blockchain is the immutability and security of data that cannot as easily be achieved with other technological systems. In order for OBR to be achieved, results of patient outcomes would need to be available to insurance companies so reimbursements can be provided to the manufacturer. This information is sensitive and is protected under the Health Insurance Portability and Accountability Act of 1996 (HIPPA). This law gives patients rights over their health information and ensures that health information is protected. Covered entities consisting of health plans, providers, and healthcare clearinghouses

must legally protect patient health information by setting up procedures to safeguard the information and keep it out of the wrong hands. This health information includes what is written in the medical records by healthcare professionals, the information the health insurer has, billing information, and conversations with doctors. Much of this is stored on Electronic Health Records (EHR), which are basically digital copies of doctor charts ("Your Rights Under HIPPA," 2017). This information is valuable and often targeted, as shown by the fact that "The healthcare industry was the victim of 88% of all ransomware attacks in U.S. industries last year" (Mulero, 2017). Given that this information is safeguarded by HIPAA and needs to stay in the right hands to not impact the patient, blockchain could securely share the information for OBR cases. Its immutability, encryption, and difficulty to hack ensure that it cannot be tampered with or stolen by malicious parties while stored in a blockchain system. Compared to current EHR systems, blockchain is a better way to aggregate the patient information for collaboration with the insurers. Since blocks are hashed, they become tamper-proof, and their encryption makes them difficult to hack. Changes cannot be made due to its immutability that would need to be verified by the entire network. Blockchain also helped with anonymity, which is imperative for sensitive information such as medical records (Hayes, 2018). Though all parties have access to the whole chain, the sensitive information can be guarded by zero-knowledge proofs or channels to share information without revealing it to the whole network. Only metadata would be available to all parties.

Smart contracts are a key component of the blockchain implementation. Smart contracts can also be employed to automatically verify data without the need for human interaction. Payments can seamlessly be transferred after they are verified on the block by the smart contracts. This ensures speed and reliability for OBR transactions that simultaneously protect the patient. Smart contracts can also be employed between the payer, manufacturers, and relevant EHR from

healthcare facilities to streamline the payment process. As mentioned, OBR may not be employed for all insurers or drugs, making it a more difficult system to implement with current systems. It would require tedious administration that would not only be time-consuming, but costly to all involved parties. Smart contracts can integrate the meticulous contractual agreements put forth for all drugs and insurers, whether it be qualified as OBR or not, to ensure that payment is made when it is contractually necessary. Because the smart contracts could pull health information from EHR if they are shared on the block, this would streamline the process greatly and alleviate the burden OBR would cause if it had to be verified manually.

In order to implement a blockchain, it is important to understand how it would be structured. Just as the DSCSA and rebate use cases, it would need to be set up as a private ledger. This would ensure confidentiality from the public and only allow pertinent entities to view sensitive information. It would also function better than a public network because it would limit the transactions made on the system. A blockchain for healthcare would need to transact about thirty million times per day. Change Healthcare was able to create a Hyperledger framework that processes fifty million times a day. A public chain would pose too slow and would not be able to meet the requirements put forth from a transaction standpoint (Hayes, 2018). Governance would also need to be established between entities. This governance may be easier to model than other use cases as almost all of the terms would be established in the OBR contracts. The main feat would be establishing a secure way to retain information from EHR systems and integrating that information in real time to complete OBR requests.

Blockchain's ability to secure information while speeding up processes with the use of smart contracts makes it favorable for administering OBR. It can work with HIPPA to maintain patient confidentiality because it sets up safeguards and can anonymously verify information. It

can also bypass bureaucracy by utilizing smart contracts and real-time information to transact

rebates and reimbursements to drug manufacturers. It would help cut costs and save time for an

OBR system because it would not require back and forth and tedious administrative work. In order

to enact an OBR payment system, blockchain is one of the only technologies that are capable.

Chapter 6

Conclusion

The blockchain is a technology that could greatly revolutionize the pharmaceutical supply

chain. Its ability to efficiently and securely store and transfer data while simultaneously automating

processes through the use of smart contracts or DApps is revolutionary. It is capable of

streamlining communication and data between key players within the supply chain. While most

information does need to be stored on the block for all to see, there are ways around that like zero-

knowledge proofs, that can be used to maintain trade secrets and confidential business agreements.

Overall, blockchain is helpful as an administrative tool because it eliminates the need for human

interaction and enables processes that occur automatically in real time. This is applicable to

payments and transfer of goods and is why it is an adept system for DSCSA, chargebacks, and

OBR.

While the technology has its benefits, there are still some challenges that lie ahead due to

the fact that it is new and has never been fully implemented. There were many trends that remained

the same amongst all the applications of blockchain and would need to be addressed before a

blockchain could be implemented. One of the biggest hurdles for blockchain implementation is

creating an industry standard. This is the biggest challenge in the DSCSA application, as all supply

chain players need to come to a consensus, whereas the other applications examined in this thesis do not require all of the players to be involved. As this is a growing issue, there may be more consensus over time, and standards will be dependent upon the problem and entities involved. Implementation and execution are also a hurdle, as a blockchain has not been commercially used throughout an entire supply chain. However, this issue will subside with time and trials. Cost plays into this issue, as companies need to evaluate their need and make the investment. Despite the hurdles, blockchains potential to create security, transparency, and efficiency in the supply chain is worth the investment.

Overall, blockchain's security and ability to create a more sufficient and transparent supply chain holds a lot of potential for the pharmaceutical industry. Its potential goes well beyond the scope of this thesis and can be applied to many other aspects of the supply chain and business in general. As it is an emerging technology, the potential to grow and create more applicability is inevitable. Once the hurdles are overcome it will allow for security and ease of transactions between the main entities in the pharmaceutical industry, and it may possess the power to shift the industry as a whole.

BIBLIOGRAPHY

Basta, Nicholas. "Blockchain: the Technology to Make DSCSA Work after 2023?"

      Pharmaceutical Commerce, 24 July 2017,

      pharmaceuticalcommerce.com/information-technology/blockchain-technology-make-

      dscsa-work-2023/.

Basta, Nicholas. Personal Interview. 11 January 2019.

"Blockchain Explained - Intro - Beginners Guide to Blockchain." *BlockchainHub*,

      blockchainhub.net/blockchain-intro/.

Bernstein, Ilisa B.G. "Drug Supply Chain Security Act (Title II of the Drug Quality and Security

      Act)." *U.S. Food and Drug Administration*, 12 Mar. 2014,

      wayback.archive-it.org/7993/20170113093353/http://www.fda.gov/downloads/Drugs/De

      velopmentApprovalProcess/SmallBusinessAssistance/UCM388945.pdf.

Bonnstetter, Evan. "'Track and Trace' Requirements for Pharmaceuticals Are Global Trend, but

      After Pilot Period Russia Postpones Introduction." *MSU Internatonal Law Review*, 31

      Mar. 2018, www.msuilr.org/msuilr-legalforum-blogs/2018/3/31/track-and-trace-

      requirements-for-pharmaceuticals-are-global-trend-but-after-pilot-period-russia-

      postpones-introduction.

Celeste, Robert. Personal Interview. 9 January 2019.

Chan, Albert. Personal Interview. 1 February 2019.

"Cryptography Explained." *Lisk*, 2018,

      lisk.io/academy/blockchain-basics/how-does-blockchain-work/blockchain-cryptography-

explained.

"Drug Supply Chain Security Act - Key Provisions of the Drug Supply Chain Security Act." *U S Food and Drug Administration Home Page*, Center for Drug Evaluation and Research, 30 June 2017, www.fda.gov/Drugs/DrugSafety/DrugIntegrityandSupplyChainSecurity/DrugSupplyChainSecurity Act/ucm565168.htm.

Hayes, Maris. "Technology Gap in Healthcare's Value Based Payment Model." *Penn State Honors Theses*, Apr. 2018, https://honors.libraries.psu.edu/files/final_submissions/5182.

Health Strategies Consultancy LLC. "Follow the Pill: Understanding the U.S. Commercial Pharmaceutical Supply Chain." *The Kaiser Family Foundation*, Mar. 2005, kaiserfamilyfoundation.files.wordpress.com/2013/01/follow-the-pill-understanding-the-u-s-commercial-pharmaceutical-supply-chain-report.pdf.

HIDA. "Improving Pricing Accuracy: Contract Communications Standards For The Healthcare Supply Chain." Health Industry Distributors Association, 2017, www.hida.org/App_Themes/Member/docs/Resources/HIDA_Improving-Pricing-Accuracy_whitepaper.pdf.

Jayachandran, Praveen. "The Difference between Public and Private Blockchain." *Blockchain Unleashed: IBM Blockchain Blog*, 31 May 2017, www.ibm.com/blogs/blockchain/2017/05/the-difference-between-public-and-private-blockchain/.

Lacoma, Tyler. "What Is a Pharmaceutical Chargeback?" Bizfluent, 21 Nov. 2018,

bizfluent.com/info-8783464-pharmaceutical-chargeback.html.

"MediLedger - Blockchain Solutions for Pharma Companies." MediLedger - Blockchain

Solutions for Pharma Companies, 2018, www.mediledger.com/.

Miller, Harold D. "From Volume To Value: Better Ways To Pay For Health Care."

Healthinsight.org, Sept. 2009,

healthinsight.org/Internal/assets/Payment_Reform/pdfs/Miller-From_Volume_to_Value-

HealthAffairsSept2009.pdf.

Mulero, Ana. "Charts: Must-Know Healthcare Cybersecurity Statistics." Healthcare Dive, 27

Feb. 2017,

www.healthcaredive.com/news/must-know-healthcare-cybersecurity-statistics/435983/.

Peterson, Taylor. "Blockchain Technology: Analysis of Application Uses Within Supply Chain."

Penn State Honors Theses, Apr. 2018,

honors.libraries.psu.edu/files/final_submissions/5071.

"Pharmaceutical Traceability." *HDA*, 2018,

www.hda.org/Issues/Pharmaceutical%20Traceability.

PhRMA. "Follow the Dollar Understanding How the Pharmaceutical Distribution and Payment

System Shapes the Prices of Brand Medicines." Phrma.org, Nov. 2017,

phrma-docs.phrma.org/files/dmfile/Follow-the-Dollar-Report.pdf.

Pulli, Linda. Personal Interview. 5 April 2018.

Reed, Christopher. "How to Comply with the U.S. Drug Supply Chain Security Act Rule Using

GS1 Standards." *gs1.Org*, 23 Oct. 2014, www.gs1.org/sites/default/files/creed_jj.pdf.

Somerville, Susanne. "How Blockchain Is Simplifying Pharmaceutical Track And Trace."

Chronicled, 20 Mar. 2018, blog.chronicled.com/how-blockchain-is-simplifying-

pharmaceutical-track-and-trace-949ce4c37daa.

Stollman, Jeffrey. Personal Interview. 11 September 2018.

"The Drug Supply Chain Security Act and Blockchain." The Center For Supply Chain Studies,

21 June 2018,

static1.squarespace.com/static/563240cae4b056714fc21c26/t/5b3a552c2b6a28f30c0c5d3

1/1530549553630/C4SCS+White+Paper_+DSCSA+and+Blockchain+Study_FINAL4.pd

f.

"The Way Drugs Are Sold & Distributed Is Opaque, Inefficient, & Costly. Here's How

Companies Are Trying To Fix That." *CB Insights Research*, 18 Sept. 2018,

www.cbinsights.com/research/drug-supply-chain-tech/?utm_source=Digital%2BHealth%

2BNewsletter&utm_campaign=00eaeab874-

DigitalNL_3_16_2017_COPY_01&utm_medium=email&utm_term=0_8f02c12568-

00eaeab874-91494589.

"Waivers, Exceptions, and Exemptions from the Requirements of Section 582 of the Federal

Food, Drug, and Cosmetic Act Guidance for Industry." *FDA.gov*, May 2018,

www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/

UCM66876.pdf

"What Is Blockchain Technology?" *CB Insights Research*, 11 Sept. 2018,

www.cbinsights.com/research/what-is-blockchain-technology/#blockchain.

Xu, L., H. Li, and H. Zhao. Outcome-Based Reimbursement: the Solution to High Drug

Spending? 2019. Working paper. Smeal College of Business. The Pennsylvania State

University. University Park.

Yeh, Brian. Personal Interview. 23 January 2019.

"Your Rights Under HIPAA." HHS.gov, US Department of Health and Human Services, 1 Feb.

2017, www.hhs.gov/hipaa/for-individuals/guidance-materials-for-consumers/index.html.

Zenk, Heather. "Understanding Blockchain for DSCSA Compliance." Amerisourcebergen.com,

5 June 2018, www.amerisourcebergen.com/abcnew/insights/understanding-blockchain-

for-dscsa-compliance.

Zenk, Heather. "Understanding the Drug Supply Chain Security Act." ASAP Net , 2015,

www.asapnet.org/files/June2015/Presentations/ASAPJune15_Presentation_09_Zenk.pdf.

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EDUCATION

The Pennsylvania State University, University Park, PA
Schreyer Honors College   Anticipated Graduation: **May 2019**
Bachelor of Science in Biomedical Engineering
Universidad de Sevilla, Seville, Spain
Study Abroad Program   Spring 2017

WORK EXPERIENCE

Risk Advisory Intern - Healthcare Industries
PricewaterhouseCoopers, Philadelphia, PA   June – July 2018
- Conducted chargeback testing and PBM reviews for pharmaceutical companies and wholesalers by comparing claims, analyzing data provided, and profiling formularies
- Documented market research interviews regarding the American Patients First Healthcare Blueprint. Conducted independent research to develop slide content summarizing international healthcare systems and industry scenarios which was later presented to the client's SVP of Finance & Strategy
- Researched the potential applications of a blockchain for medical device asset tracking. Created a deck that compared blockchain technology to a cloud based CRM, and weighed the pros and cons of each. Presented to a group of PwC directors.
- Served as the team leader for the Intern Case Competition to plan and coordinate meetings, set agendas, and ensure tasks were completed on time. Worked with the team to research effects of Big Data on Healthcare and Consumer Markets and what they would mean to PwC. Presented the findings to a board of judges.

Clinical Supply Chain (CSC) Strategy Co-op
Johnson & Johnson - Janssen R&D, Titusville, NJ   June – December 2017
- Identified a need for a New Hire App; Developed and pitched idea to organization-wide Onboarding team, and successfully secured funds and resources to create and launch the app for future new hires
- Project management lead of CSC Core Team for cross pharma PDMS Playbook
- Led initiative to design and incorporate Playbook Learning Modules as onboarding tools, creating a better overview of the organization and new hire role while promoting the use of the PDMS Playbook
- Streamlined an electronic archiving system to maintain audit readiness & compliance by creating a storyboard & content map
- Titusville site Safety Lead within CSC planning safety events quarterly and increasing the number of CSC employees that received ergonomic assessments from 23% to 100%
- Volunteer lead for CSC Credo Team leveraging J&J resources and leading volunteer and Credo events
- Site volunteer lead for the Mental Health Diplomats to coordinate Mental Health First Aid Training on site
- Volunteer champion for the J&J crowdfunding platform, Caring Crowd; led a campaign that raised $5,000
- Successfully recruited, interviewed, and hired replacement to ensure a continuous talent pool within CSC

Research Assistant
Penn State Rolls Drosophila Neuron Lab, University Park, PA   October 2015 – December 2016
- Led a project on microtubule polarity and its role in maintaining neuron structure
- Created recombinant DNA using infusion reactions to insert in Drosophila
- Examined effects of recombinant DNA to localization of proteins in neurons of Drosophila

LEADERSHIP

Professional Development Chair, Johnson & Johnson Intern Co-op Association   September 2017 – December 2017
- Planned bimonthly events for Interns & Co-ops to help them network and learn from experienced employees

Chapter President, Alpha Omicron Pi Sorority   December 2015 – December 2016
- Elected out of 211 members to work with Panhellenic and Headquarters to manage risks
- Planned philanthropy and programming events with the executive board that completed 20% more requirements than before, and earned the highest level of recognition from Headquarters

CERTIFICATIONS & AWARDS

Lean Six Sigma Yellow Belt Certified
Mental Health First Aid Certified
Encore Award for Credo Initiative Organization and Passion | Johnson & Johnson   October 2017
Encore Award for Extraordinary effort on V-TMF update & Storyboard | Johnson & Johnson   October 2017
Encore Award for Great continuous improvement process using new app | Johnson & Johnson November 2017
Encore Award for Creative vision in the Playbook Learning Cycles for PDMS| Johnson & Johnson November 2017
Encore Award for Mental Health First Aid Training leadership | Johnson & Johnson   December 2017