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Innovative Research Trends in Science and Technology Volume II

Editors:
Dr. Shakeel Ahmed Adhoni
Dr. Malathi H.
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PREFACE

Science and technology have always been the cornerstones of human progress, driving innovation and transforming societies across generations. In today's fast-paced and interconnected world, research in these fields holds unparalleled significance as it shapes the trajectory of global development. With the constant evolution of knowledge, new trends in scientific exploration and technological advancement emerge, offering innovative solutions to the challenges of our times.

This book, Innovative Research Trends in Science and Technology, is a testament to the creative and relentless pursuit of excellence by researchers from diverse domains. It encapsulates cutting-edge studies and groundbreaking discoveries that highlight the dynamic interplay between science and technology. From fundamental scientific inquiries to practical applications, the chapters presented herein reflect the interdisciplinary approach that is increasingly defining modern research.

The contributors to this volume are experts and visionaries who delve into topics ranging from advanced materials, sustainable technologies, and computational sciences to life sciences, engineering innovations, and beyond. By bringing together these diverse perspectives, the book seeks to provide a comprehensive understanding of how novel ideas and research methodologies are shaping the future.

This compilation is not just a repository of knowledge but also a source of inspiration for scholars, professionals, and enthusiasts who wish to explore the frontiers of science and technology. It aims to spark curiosity, foster collaboration, and encourage further exploration in these vital fields.

We extend our heartfelt gratitude to the authors for their invaluable contributions and to all those who have supported the realization of this publication. May this book serve as a beacon for aspiring researchers and a platform for disseminating knowledge that propels humanity toward a brighter future.

- Editors

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ADVANCED WATER FLOODING FOR THE APPLICATION OF ENHANCED OIL RECOVERY

Prasenjit Talukdar*[1], Gaurav Himanta Khaklari[2],
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Abstract:

Water flooding is the most widely used enhanced oil recovery method and finds significant applications worldwide. Its major role is in the tertiary enhanced oil recovery process. In recent years, the oil industry has greatly become interested in advanced waterflooding techniques, especially for the residual oil recovery. Advanced water injection, also known as smart water flooding, seeks to change wettability and decrease residual oil saturation by using low-salinity water and altering the ionic properties of the injected water. Smart water flooding has been reported to be successful in various reservoirs. In naturally fractured, low-permeability tight oil reservoirs, smart water may increase the oil recovery by up to 3%. Clay particles in sandstone significantly impact wettability alteration, making the sandstone reservoir favorable for this technique. The process involves a number of mechanisms working simultaneously to improve oil recovery more effectively than individual mechanisms. Smart water flooding lowers interfacial tension and changes the wettability of the rock. When the concentration of the $(SO_4)^{2-}$ ions was increased by 2.5 times, it was found that this increased the alteration of wettability to its highest value, reducing the contact angle from 145.9° to 54.4°, thus increasing the recovery percentage from 45.2% to 72%. Elevated temperatures, such as 70°C, were also found to increase the recovery. Nanoparticles are being used in association with smart water to maximize its effectiveness. They enable the regulation of sanding, a critical issue of sandstone reservoirs; they enhance injectivity without the pores clogging. Environmentally friendly, these small particles can be used at deep, high-temperature, and high-pressure reservoirs. This paper gives a theoretical overview of the applications and outcomes of smart water flooding across various types of reservoirs, showing its potential for improving recovery factors and addressing challenges in advanced oil recovery.

Keywords: Low Salinity Water; Wettability; Residual Oil Saturation; Water Flooding.

Introduction:

Advanced water flooding is referred to the achievement of enhanced oil recovery in which the ionic composition of the injected brine is altered directly. *J.Hao et al. (2019)* stated that in the case of sandstone reservoirs, the process of smart water flooding is frequently noted with low salinity flooding but it is more varied in the case of carbonate ones (Hao *et al.,* 2019). Smart water flooding in carbonates has been an interesting area of research lately. It is an optimization of ion concentrations for the sake of enhanced oil recovery by altering the composition of injected fluid, thereby modifying the equilibrium of the original crude oil-brine system. This changes the wetting conditions and enhances oil displacement through the porous medium. Interaction of the circulating oil with the water in the porous medium is related to contact with the rock surface and interfaces of fluids (oil and brine) (Austad, 2013). As there were no uses of special oil recovery chemicals, water flooding was considered a secondary oil recovery process instead of an enhanced process. Earlier water flooding had the basic purpose of displacing the oil and providing a pressure support system. During the last 30-20 years it was discovered that alteration in wetting property could improve the recovery of oil (Austad, 2013). *Montazeri et al. (2020*) said that different mechanisms are applied for limestone and carbonate reservoirs as the wetting property ranges are different in each case (Soleimani *et al.,* 2021).

In advanced water flooding, the salinity of the injected brine determines the alteration of wettability in the reservoir that enhances the recovery factor. It is established that small pores are water-wet, while large pores are oil-wet. Modification of the salinity of the injected water makes the reservoir change from a water-wet condition to mixed-wet conditions, and thereby enhances oil recovery. P. Soleimani's study showed that when the ionic strength of the injected water did not exceed the critical flocculation concentration, the observed particle migration in the porous medium was classified as a fine migration. Low salinity water injection into the aqueous phase was used to expand and remove the oil layer, shifting the mixed-wet system to completely water-wet conditions that dramatically improved the recovery factor (Soleimani *et al.,* 2021). Another benefit of low-salinity water injection is that it increases the pH of the system. This is because the hydrogen ions are released from the water to the rock surface, and sodium ions are absorbed from the rock surface. The increase in pH causes a change in the zeta potential, resulting in the desorption of organic materials from the rock surface and reducing the IFT between water and crude oil. This reduction in IFT is due to reactions between organic acids in the crude

oil, which encourage the formation of surfactants. Low-salinity water injection also allows for the removal of organometallic compounds and oil-wet surfaces through multicomponent ion exchange, which increases the oil recovery. Organometallic compounds are produced by the reaction of divalent ions at the rock surface with polar compounds in the oil, such as resins and asphaltenes. As the salinity of the injected water decreases, more organic materials dissolve in the water, which increases the oil recovery. Low-salinity water, which has pathways in the form of oil droplets, displaces oil and reduces the contact angle (Hossein *et al.,* 2024). This process alters wettability significantly, making the system more water-wet and further enhancing recovery. Temperature also impacts wettability alteration profoundly, and higher temperatures enhance the effects of these mechanisms. Low-salinity water flooding is, therefore, an effective strategy for enhancing oil recovery in reservoirs under favorable conditions (Bai *et al.,* 2021).

Enhanced Oil Recovery using Advanced water in Carbonate Reservoirs

Advanced Water injection is an Enhanced Oil Recovery method (EOR) that can be effectively enhanced by formulating smart water in terms of low salinity and altering the ionic properties of water that is being used. *Fathi et al. (2011)* discussed the effectiveness of advanced water in recovering oil in the temperature range of 70-120^{o}C. They found that advanced water improves the oil recovery by modifying the wettability of the rock from oil-wet to water-wet or neutral wet. Seawater increases the water wettability of reservoirs by 11% whereas else diluted seawater did not bring any significant changes to the water wet area but surprisingly seawater with NaCl depletion was found to enhance the water wet area by 29%. In higher temperatures, the wettability alteration is high using seawater and modified seawater which leads to improvement in oil recovery.

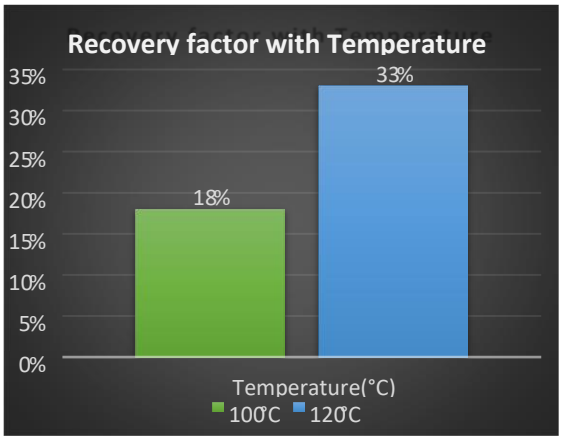

Figure 1: Recovery factor for Oil

At 100 ^{o}C when seawater depleted in NaCl spiked with SO_4^{2-}, the oil recovery was about 18% of original oil in place (OOIP), but when it was injected at 120 ^{o}C the oil recovery was 33% of OOIP (as shown in fig no. 1). The recovery of oil was highly affected by the increase in the concentration of sulphate.

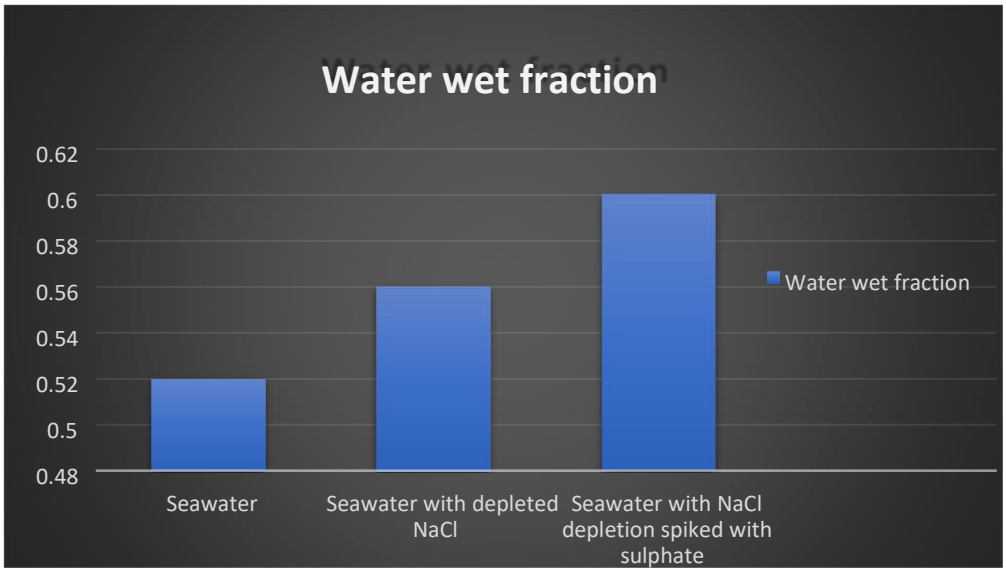

Figure 2: Water wet factor in a reservoir

The oil recovery increased in the order of formation brine<Seawater<Seawater with NaCl depletion<Seawater with NaCl depletion spiked with sulphate. The water-wet fraction for seawater, seawater with depleted NaCl, and seawater with NaCl depletion spiked with sulphate were found to be 0.52, 0.56, and 0.6 respectively (as shown in fig no. 2) by performing chromatographic wettability test (Fathi *et al.,* 2011). For the imbibing fluid to act as a wettability modifier, sulphate and non-active salt like NaCl plays a major role in it. It completely depends upon the technique of economic preparation of specific fluid for field application of seawater as an EOR fluid in carbonates (Fathi *et al.,* 2012). *Soleimani et al. (2020)* studied the combined effect of both carbonated and advanced water injection in oil recovery i.e. they investigated the hybrid advanced water carbonated injection. The primary and important properties that were affected by injection of hybrid carbonated smart water are pH variation, oil swelling, oil viscosity reduction, ion concentration variation in brine and porous media, and wettability alteration. This method resulted in the highest recovery leading to 70% of oil recovery; this was possible due to enhancement in permeability, ion exchange, wettability alteration, and oil swelling. The wettability changes from oil-wet to water-wet when formation carbonated brine is added this is because the negative oil part is substituted by SO_4^{2-} ions. The highest Recovery factor (RF) is found in 100 times diluted formation carbonated brine because with dilution the salinity is lowered

than formation water and more volume of CO_2 is dissolved (Soleimani *et al.,* 2020). *Arshad et al. (2017)* stated that another reason for the increase in oil recovery is the formation of water-soluble oil emulsions during the use of smart water (Arshad *et al.,* 2017). *Awolayo et al. (2014)* performed the various experiment and dawn to a conclusion that the degree of wettability alteration is a function of surface charge alteration present at the two surfaces when there is more concentration of sulphate than the two surfaces possess more similar charges at the interface as a result stronger repulsive forces are generated which alters the wettability (Awolayo *et al.,* 2014). Enhanced oil recovery can be quite challenging for carbonate reservoirs as they are mostly oil wet and naturally fractured so oil recovery from such reservoirs can be difficult at times*. Muro et al.* (2014) investigated the recovery of heavy oil from carbonate reservoirs under high temperatures with the application of smart water injection. It was later found that advanced water plays a significant role not only in the recovery of light oil but was extremely applicable for the recovery of heavy oil from carbonate reservoirs. An additional 8% recovery of oil was found from the soak period as within that period the contact between the water and core increased and as a result water even reached the unwept region of the reservoir. There is no direct relationship between pH variation and oil recovery (Gachuz-Muro & Sohrabi, 2014). *Fani et al. (2019)* discussed "Shock slug" which aims in tertiary recovery using smart water. Through pH analysis in a short duration time, it came to notice that advanced water interacts with the rock surface efficiently even in a short period. Recovery increased in a considerable amount in tertiary mode by application of advanced water shock slug. Both smaller as well larger advanced water shock slug were effective in increasing tertiary recovery (Fani & Al-Hadrami, 2018). *Ghosh et al. (2016)* studied the scale precipitation during injection of advanced water. Upon mixing with formation water, some high-profile advanced water was often found to cause precipitation of sulphate scales. This scaling potential can be predicted through computer simulation. One compound that was found quite effective in the prevention of scale deposition was Polysulphate-M which reduced the formation damage that was caused by the mixed water. Polysulphate-M was found successful in releasing the trapped oil from the formation and also it converted the oil-wet reservoir more towards a water-wet reservoir.

Advanced water in Tight Reservoirs

Oil recovery in tight reservoirs was increased by the application of advanced water as it altered the wettability also the residual oil saturation was reduced by 5% by the employment of low salinity water. Advanced water flooding in tight reservoirs can increase

oil recovery while decreasing water production. It also reduces the relative permeability of water in tight oil reservoirs. In advanced water flooding even with less cumulative water injection, the oil production is higher than high salinity water flooding. Through the mineral dissolution process advanced water is found to improve effective permeability (Kadeethum *et al.,* 2017). *Xie et al. (2015)* investigated low salinity waterflooding for a tight oil reservoir. It showed the low salinity waterflooding application towards reservoir with low permeability, formation salinity of up to 45,180ppm, in-situ oil viscosity of 0.6 centipoises, and reservoir temperature of 70 ^{o}C. Results that were found proved that ion tuning water along with a few fractions of low salinity water was capable of increasing oil recovery from tight oil reservoirs (Xie *et al.,* 2015). Advanced water leads to the enhancement of microscopic sweep efficiency. Higher cation exchange capacity (CEC) in tight oil reservoirs helps in wettability alteration processes although they have limited flow capability. The CEC distribution in the system is influenced by the mean and variance of porosity. Advanced water flooding can improve oil recovery by 3% and reduce water production in tight oil reservoirs (Carpenter, 2017).

Advanced Water Flooding in Sandstone Reservoirs

The initial wettability and the altered wettability must be understood clearly for a better and optimized design of advanced water. *Mamonov et al. (2017)* studied the effect of sandstone on initial wettability and the wettability after alteration during advanced water injection. There is a potential for low salinity advanced water EOR in a sandstone reservoir. In sandstone reservoir, clay particle has the most significant effect when advanced water is injected as they contribute most to the active pore surface thereby influencing the wettability. For observing advanced water EOR effects in sandstone presence of clay minerals is a must. On the other hand, feldspar mineral is responsible for the pH of the reservoir. Feldspar may behave as useful or harmful depending upon the composition of the formation water. Evaporates minerals are found to reduce or delay low salinity EOR effects due to their dissolution which will result in an increased amount of Ca^{2+} ions, hence will reduce the ion exchange at the mineral surfaces (Mamonov *et al.,* 2017).

Advanced water combined with anionic and cationic surfactants

When advanced water was used along with surfactants the results were more desirable i.e., the recovery factor was highest when optimum advanced water was used along with optimum concentrations of surfactants. Surfactants can reduce the contact angle and thereby altering the wettability. The results proved that advanced water along with

surfactants in carbonate reservoirs was able to change the wettability more toward water wet. The oil recovery factor obtained by using distilled water, seawater, and advanced water with a combination of optimum concentration of surfactants was found to be 28%, 42%, and 58% respectively. Hence a combination of advanced water and surfactants was found to be more beneficial than advanced water alone (Mofrad & Saeedi Dehaghani, 2020).

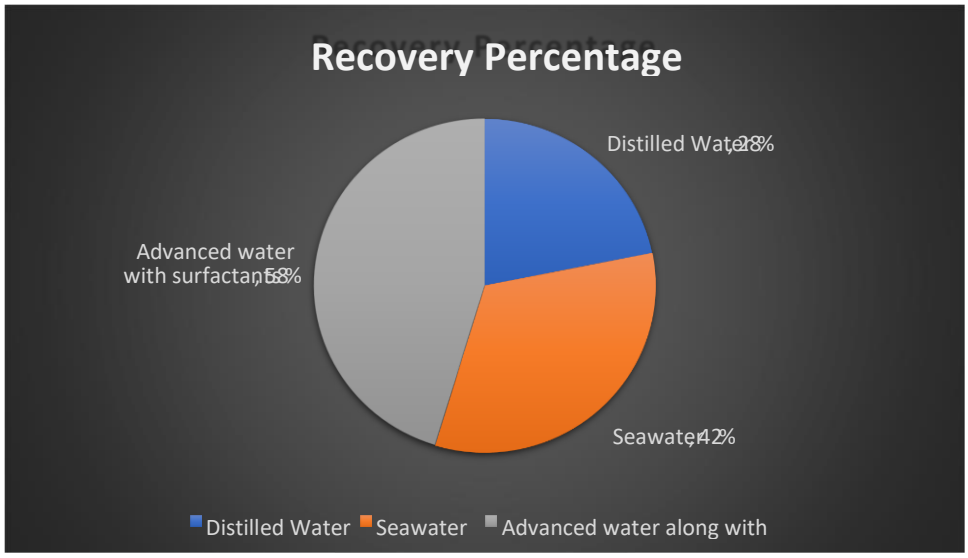

Figure 3: Percentage of Recovery

Comparision of advanced waterflooding in limestone and sandstones

Advanced water flooding is an advanced technique that alters the cation concentration, such as $(SO_4)^{2-}$, Ca^{2+} and Mg^{2+} to improve oil recovery (Montazeri *et al.,* 2020). According to T. Austad, many studies have established that low-salinity water flooding in sandstone reservoirs with salinity between 1000 to 2000 ppm yields a significant improvement in oil recovery (Austad, 2013). Austad stated specific conditions in his study wherein salinity changes are indeed efficient. Among them are clay minerals, which must be present within the porous media of sandstone and polar components like acids or bases present within the oil. Additionally, the formation water (FW) containing divalent cations such as Ca^{2+} and Mg^{2+} is necessary. The range of salinity is crucial, though it usually falls in between 1000 and 2000 ppm. However, the range can go up to 5000 ppm at times. Importantly, the technique has no temperature constraint. It can be applied for all the reservoir conditions.

It was found that due to mineralogical properties the study of sandstone's low water salinity was difficult as compared to that of carbonate and the wettability alteration in carbonates was the result of the geochemical interaction (Sharma & Mohanty, 2017). Many

mechanisms were probably expected to be acting simultaneously that caused the effect of the low water salinity. The most common mechanism accepted was that of the alteration in the wettability but some other mechanisms that are considered to cause this effect are like blocking the pore spaces by the fine migration and exchange of the multicomponent ions. But the latter mechanisms never got general acceptance as there were some contradictions observed in the experimental facts (Austad, 2013).

In the case of a carbonated reservoir like limestone, it was recently observed that it showed an active reaction towards active ions in advanced water (AW) but there was a little alteration in the reactivity towards Ca^{2+} and Mg^{2+} ions. It was observed by researchers that the water wet surface of the limestone reservoir after it was precleaned with toluene and methanol and water flooded with AW at a temperature of 130°C was increased by a percentage of 30. It was further observed in the case of a low permeable limestone reservoir that the oil recovery rate improved from 8% to 37% when the imbibing fluid was altered from FW to AW. But there was a slight change noticed during studies, the limestone outcrop and limestone reservoir showed a difference in wettability alteration (Austad, 2013). It was expected for potential determining ions like Ca^{2+}, Mg^{2+}, and $(SO_4)^{2-}$ ions to play a significant role in wettability alteration in the case of carbonates (Sharma & Mohanty, 2017)(Bai *et al.,* 2021). Limestone outcrops were studied and it was found that the outcrop remained nonreactive towards potential determining ions and wettability altered in presence of crude oil but no recovery was seen using AW even by increasing the temperature (Austad, 2013).

Different mechanisms found in Sandstones and Carbonate Reservoirs

Rafieiet al. (2021) stated that in the entire lifespan of a petroleum reservoir, three periods were available for fluid production- the primary period, the second period and the reservoir pressure decreased during this period, and lastly the tertiary period (Rafiei & Khamehchi, 2021). Maximization of the recovery is the main principle of waterflooding. Earlier importance was given to the improvement of volumetric sweep efficiency through various processes and a little importance was given to the waterflooding process but lately, research had shown that it caused an important effect on oil recovery. In the last two decades, many postulates have been put forward to understand the mechanism of the low salinity water flooding but all the remained uncertain (Yousef *et al.,* 2011). The proposed mechanisms cited in the case of sandstone rocks were multiple components ionic exchange causing wettability changes, electrical double layer expansion, migration of the fines,

selective plugging, emulsification (Namaee-Ghasemi *et al.,* 2021) decrease of interfacial tension due to increase in pH (Yousef *et al.,* 2011).

Researchers, including Rezaeidoust et al. (2009), have discovered that advanced water flooding improves the water-wetness of carbonate reservoirs at high temperatures. The possible mechanisms for wettability alteration in the case of carbonates may be surface charge change, dissolution of minerals, and expansion of electrical double layer (EDL) (Namaee-ghasemi *et al.,* 2021). In the sandstone reservoir, the existence of clay minerals proves to be the factor in enhanced water-wetness. Those clay particles are known for improvement of water-wetness, with a consequent increment of the microscopic sweep efficiency toward more desirable oil recovery (Rezaeidoust *et al.,* 2009).

Amongst all the early put forward mechanisms of alteration of wettability through AW flooding in carbonates, one of them was the ion exchange at the surface. In this process, the positive surface of the carbonate rock absorbed the $(SO_4)^{2-}$ ions causing a reduction of its charge and thus letting Ca^{2+} ions liberate carboxylic material as close as possible to the surface. Mg^{2+} ions started substituting Ca^{2+} ions as they started to become more reactive thus altering the wettability and increasing the oil recovery. It was found by the author in some studies that Mg^{2+} ions have the potential to change the wettability solely (Namaee-ghasemi *et al.,* 2021).The amount of positive charge was deducted by the $(SO_4)^{2-}$ ions which acted as a catalyst. It was also documented that the movement of minerals from rock surfaces was also decreased by the presence of nanoparticles (Rafiei & Khamehchi, 2021).

A. Namaee-Ghasemi et al. investigated zeta potential to analyze surface alteration of carbonate rocks. They reported zeta potential to be proportional to the salinity of brine, with Ca^{2+} and Mg^{2+} ions are moving from rock to brine to maintain equilibrium. Calcite patches exhibited LSE without rock dissolution, which improved IFT. Zeta potential, determined by contact angle differences, was found to be a critical factor in oil recovery and was affected by pH changes (Namaee-Ghasemi *et al.,* 2021). The authors Ahmed Kasha *et al.,* also researched and documented that the negative zeta potential was turned more negative by the effect of $(SO_4)^{2-}$ ions, and on further dilution of seawater the negative charges on the surface of the carbonate rock particles became higher (Kasha *et al.,* 2015).

Of all the mechanisms, wettability alteration has remained the driving mechanism for better oil recovery as it changes not only the salinity but also the ionic compositions of the injected fluid (Yousef *et al.,* 2011). The variation in the adsorption strength is the main

difference between the wetting properties of carbonates and sandstones (Rezaeidoust *et al.,* 2009).

Nano-Particles and Nano Composite in Advanced Water Flooding in Enhanced Oil Recovery

During CO_2 flooding, the serious gas channelling occurs in ultra-low permeability reservoirs due to high mobility of CO_2. So, to solve this problem we have to find out responsive nanoparticles for mobility control. The new responsive solution is developed by modifying nanoparticles based on nano silica (SiO_2) by 3-aminopropyltrimethoxysilane (KH540) via Eschweiler-Clark reaction by *Lai et al. (2020)* (Lai *et al.,* 2020). The sand production is still a most common problem in sandstone reservoir because rock wettability alteration toward water wetting is the main cause of sand production during the smart water injection mechanism. The nano-particles, has been implemented to prevent sand production. With the silica nano-particles (SiO_2) up to an optimum concentration of 2000 ppm in smart water (pH=8). It is found that the effect of wettability alteration of oil wetted sandstones on sand production in the presence of advanced water with nano particles is significantly reduced sand production by *Bahri et al. (2020)* (Bahri & Khamehchi, 2020). Only few numbers of researches is conducted for the implementation of nano-particles in advanced water as enhanced oil recovery.

The experimental result also found with increasing the concentrations of calcium and sulphate ions in advanced water; oil recovery is improved by 9% and 10%, respectively, compared to seawater performed by *Habibi et al. (2020)* (Habibi *et al.,* 2020). The advanced water containing two times of sulphate ions concentration (SW2S) with nano-fluids, showing increased efficiency of about 7.5% (Habibi *et al.,* 2020). In resent finding shows that mono-valent ions had better potential than the divalent ions because of having more negative zeta potential and less ionic strength. The low-salinity water can also reduce the contact angle between oil and water. By adding SiO_2nano-particles up to 0.05 wt% increased oil recovery by about 4% OOIP more than the low-salinity water flooding found by Ebrahim et al. (2019) (Ebrahim *et al.,* 2019). CO_2 flooding decreases the oil–water interfacial tension and oil viscosity; it also improves the mobility ratio. It is most abundant and also nontoxic. So, it is highly effective technology for EOR in case of ultra-low permeability reservoirs. However, it has certain disadvantages, such gas channelling it happen due to high mobility of CO_2. The conventional methods used to control CO_2 gas channelling are gel injection, foam injection and polymer injection. However, SiO_2 showed

better CO_2 mobility control performance. Due to the unique properties of nano- scale particles by modifying the surfaces of SiO_2 nano-particles causes it to have better effects on CO_2/N_2 response compared with the amidine group. However, after developing this application, it would be certainly open up to a responsive nano-SiO_2 as a new important frontier (Lai *et al.,* 2020). In sandstone reservoirs, sand production is the biggest challenges that we are facing. It causes damage to equipment and also well tools, corrosion and erosion of pipelines, plugging the pipelines and wells, disturbance of wellbore stability.

Sand production takes place when particle stress exceeds the strength of the rock. It increases with drag force but decreases with higher clay content. The surfaces of sandstone are negatively charged at reservoir pH levels. Wettability can be altered from highly water-wet to strongly oil-wet. Thus, a careful evaluation of initial wettability is essential for successful wettability alteration. Chemical methods, especially nanoparticles, are the most effective. Mechanical methods and techniques like acidizing, polymer flooding, and resin injection are less economical and may cause a decrease in permeability and production. Bahri et al. showed that silica oxide nanoparticles at a concentration of 0.1 wt.% decreased formation particle production by 80% ((Lai *et al.,* 2020). Nanoparticles, being microscopic in size, enter pores without blocking them and reduce injectables during flooding. They are environmentally friendly compared to other chemical flooding materials and can be used in deep reservoirs under high temperature and pressure, though their transformation or removal requires significant energy (Habibi *et al.,* 2020).

Conclusion:

Advanced water injection can be well optimized when low salinity water is used and changes in ionic properties can be useful for more oil recovery. The main motive of advanced water injection is to alter the wettability from oil-wet to water, thereby reducing the residual oil saturation. Seawater depleted in NaCl spiked with SO_4^{2-} has the greatest impact on oil recovery. By the use of low salinity smart water in tight oil reservoirs, the oil recovery can be increased by 3% and residual oil saturation can be reduced by 5%. Among the sandstone particles, clay plays a major role in enhancing the recovery through advanced water injection. Advanced water when used along with some cationic and anionic surfactant was found to have more oil recovery than the case when smart water was injected alone. With all citations and studies, advanced water flooding has a greater potential of recovering more oil than normal seawater flooding. Advanced water flooding can be low salinity hot water flooding or surfactants mixed with low salinity water. It is

applicable in both carbonates as well as sandstone reservoirs. It is also cost-effective in recovering heavy oil from the reservoir than any other tertiary methods like chemical flooding, polymer flooding, etc. With all the references studied, we can say that by injecting advanced water we can improve the recovery of oil both from carbonates and sandstone rocks. Many mechanisms take place in this instance like wettability alteration, fine migration, emulsion, double layer expansion. But is not possible at present time to state which of the mechanisms is of greater importance.

References:

1. Arshad, M. W., Fosbøl, P. L., Shapiro, A., & Thomsen, K. (2017). Water-oil emulsions with fines in smart water enhanced oil recovery. *Society of Petroleum Engineers - SPE Kuwait Oil and Gas Show and Conference 2017*. https://doi.org/10.2118/187620-ms
2. Austad, T. (2013). Water-Based EOR in Carbonates and Sandstones: New Chemical Understanding of the EOR Potential Using "Smart Water." In *Enhanced Oil Recovery Field Case Studies* (First Edit). Elsevier Inc. https://doi.org/10.1016/B978-0-12-386545-8.00013-0
3. Awolayo, A., Sarma, H., & AlSumaiti, A. M. (2014). A laboratory study of ionic effect of smart water for enhancing oil recovery in carbonate reservoirs. *Society of Petroleum Engineers - SPE EOR Conference at Oil and Gas West Asia 2014: Driving Integrated and Innovative EOR*, 46–69. https://doi.org/10.2118/169662-ms
4. Bahri, A., & Khamehchi, E. (2020). *Interfacial Phenomena Effect on Sand Production Due to Optimized Smart Water with / without the Presence of Nanoparticles*. *10*(6), 6652–6668.
5. Bai, S., Kubelka, J., & Piri, M. (2021). Wettability alteration by Smart Water multi-ion exchange in carbonates: A molecular dynamics simulation study. *Journal of Molecular Liquids*, *332*, 115830. https://doi.org/10.1016/j.molliq.2021.115830
6. Carpenter, C. (2017). Enhanced sweep efficiency by use of smart water in tight oil reservoirs. *JPT, Journal of Petroleum Technology*, *69*(10), 83–84. https://doi.org/10.2118/1017-0083-jpt
7. Ebrahim, T., Sefti, V., Shadman, M., Mahdi, M., & Tooseh, K. (2019). Performance of low - salinity water flooding for enhanced oil recovery improved by - SiO 2 nanoparticles. *Petroleum Science*, *16*(2), 357–365. https://doi.org/10.1007/s12182-018-0295-1
8. Fani, M., & Al-Hadrami, H. (2018). *2 Spe-193014-Ms*.
9. Fathi, S. J., Austad, T., & Strand, S. (2011). Water-based enhanced oil recovery (EOR)

by “smart water”: Optimal ionic composition for EOR in carbonates. *Energy and Fuels*, *25*(11), 5173–5179. https://doi.org/10.1021/ef201019k

10. Fathi, S. J., Austad, T., & Strand, S. (2012). Water-based enhanced oil recovery (EOR) by “smart water” in carbonate reservoirs. *Society of Petroleum Engineers - SPE EOR Conference at Oil and Gas West Asia 2012, OGWA - EOR: Building Towards Sustainable Growth*, *1*, 349–362. https://doi.org/10.2118/154570-ms
11. Gachuz-Muro, H., & Sohrabi, M. (2014). Smart water injection for heavy oil recovery from naturally fractured reservoirs. *Society of Petroleum Engineers - SPE Heavy and Extra Heavy Oil Conference - Latin America 2014, LAHO 2014*, 857–876. https://doi.org/10.2118/171120-ms
12. Habibi, S., Jafari, A., & Fakhroueian, Z. (2020). Wettability alteration analysis of smart water / novel functionalized nanocomposites for enhanced oil recovery. *Petroleum Science*, *17*(5), 1318–1328. https://doi.org/10.1007/s12182-020-00436-y
13. Hao, J., Mohammadkhani, S., Shahverdi, H., Esfahany, M. N., & Shapiro, A. (2019). Mechanisms of smart waterflooding in carbonate oil reservoirs - A review. In *Journal of Petroleum Science and Engineering* (Vol. 179). Elsevier B.V. https://doi.org/10.1016/j.petrol.2019.04.049
14. Hossein, A., Dehaghani, S., & Daneshfar, R. (2024). Experimental investigation of the sequence injection effect of sea water and smart water into an offshore carbonate reservoir for enhanced oil recovery. *Scientific Reports*, *0123456789*, 1–14. https://doi.org/10.1038/s41598-024-55440-8
15. Kadeethum, T., Sarma, H. K., & Maini, B. B. (2017). Enhance microscopic sweep efficiency by smart water in tight and very tight oil reservoirs. *Society of Petroleum Engineers - SPE Unconventional Resources Conference 2017*, 218–239. https://doi.org/10.2118/185032-ms
16. Kasha, A., Al-hashim, H., Abdallah, W., Taherian, R., & Sauerer, B. (2015). Colloids and Surfaces A : Physicochemical and Engineering Aspects Effect of Ca 2 + , Mg 2 + and SO 4 2 − ions on the zeta potential of calcite and dolomite particles aged with stearic acid. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *482*, 290–299. https://doi.org/10.1016/j.colsurfa.2015.05.043
17. Lai, N., Zhu, Q., Qiao, D., Chen, K., Wang, D., & Tang, L. (2020). *CO 2 / N 2 -Responsive Nanoparticles for Enhanced Oil Recovery During CO 2 Flooding*. *8*(May), 1–9. https://doi.org/10.3389/fchem.2020.00393

18. Mamonov, A., Puntervold, T., & Strand, S. (2017). EOR by smart water flooding in sandstone reservoirs - Effect of sandstone mineralogy on initial wetting and oil recovery. *Society of Petroleum Engineers - SPE Russian Petroleum Technology Conference 2017*. https://doi.org/10.2118/187839-ms
19. Mofrad, S. K., & Saeedi Dehaghani, A. H. (2020). An experimental investigation into enhancing oil recovery using smart water combined with anionic and cationic surfactants in carbonate reservoir. *Energy Reports*, *6*, 543–549. https://doi.org/10.1016/j.egyr.2020.02.034
20. Montazeri, M., Fazelabdolabadi, B., Shahrabadi, A., Nouralishahi, A., HallajiSani, A., & Moosavian, S. M. A. (2020). An experimental investigation of smart-water wettability alteration in carbonate rocks–oil recovery and temperature effects. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *00*(00), 1–13. https://doi.org/10.1080/15567036.2020.1759735
21. Namaee-ghasemi, A., Behbahani, H. S., Kord, S., & Shari, A. (2021). *Simulation and analysis of dynamic wettability alteration and correlation of wettability-related parameters during smart water injection in a carbonate core*. *331*. https://doi.org/10.1016/j.molliq.2021.115741
22. Namaee-Ghasemi, A., Behbahani, H. S. zadeh, Kord, S., & Sharifi, A. (2021). Geochemical simulation of wettability alteration and effluent ionic analysis during smart water flooding in carbonate rocks: Insights into the mechanisms and their contributions. *Journal of Molecular Liquids*, *326*. https://doi.org/10.1016/j.molliq.2020.114854
23. Rafiei, A., & Khamehchi, E. (2021). Design of smart water composition based on scale minimization and its effect on wettability alteration in the presence of nanoparticles and mineral scales. *Journal of Petroleum Science and Engineering*, *196*(August 2020), 107832. https://doi.org/10.1016/j.petrol.2020.107832
24. Rezaeidoust, A., Puntervold, T., Strand, S., & Austad, T. (2009). *Smart Water as Wettability Modifier in Carbonate and Sandstone : A Discussion of Similarities / Differences in the Chemical Mechanisms*. *12*, 4479–4485. https://doi.org/10.1021/ef900185q
25. Sharma, H., & Mohanty, K. K. (2017). An experimental and modeling study to investigate brine-rock interactions during low salinity water flooding in carbonates. *Journal of Petroleum Science and Engineering*.

https://doi.org/10.1016/j.petrol.2017.11.052

26. Soleimani, P., Shadizadeh, S. R., & Kharrat, R. (2020). Experimental investigation of smart carbonated water injection method in carbonates. *Greenhouse Gases: Science and Technology*, *10*(1), 208–229. https://doi.org/10.1002/ghg.1948
27. Soleimani, P., Shadizadeh, S. R., & Kharrat, R. (2021). Experimental assessment of hybrid smart carbonated water flooding for carbonate reservoirs. *Petroleum*, *7*(1), 80–90. https://doi.org/10.1016/j.petlm.2020.03.006
28. Xie, Q., Ma, D., Wu, J., Liu, Q., Jia, N., & Luo, M. (2015). Potential evaluation of ion tuning waterflooding for a tight oil reservoir in jiyuan oilfield: Experiments and reservoir simulation results. *Society of Petroleum Engineers - SPE Asia Pacific Enhanced Oil Recovery Conference, EORC 2015*, 239–254. https://doi.org/10.2118/174584-ms
29. Yousef, A. A., Al-Saleh, S., & Al-Jawfi, M. (2011). New recovery method for carbonate reservoirs through tuning the injection water salinity: Smart WaterFlooding. *73rd European Association of Geoscientists and Engineers Conference and Exhibition 2011: Unconventional Resources and the Role of Technology. Incorporating SPE EUROPEC 2011*, *4*, 2814–2830. https://doi.org/10.2118/143550-ms

A SURVEY ON JAVA PROGRAMMING LANGUAGE AND METHODS OF IMPROVISATION

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Abstract:

In this paper, I have conducted an audit of the Java programming language, specifically focusing on its use in student education. The paper presents four models aimed at helping students better understand Java concepts. It also surveys recent research on programming languages and the development of various models. Enhancements in error handling in recent years have allowed for the creation of structures that support messaging in the classroom. Learning involves both understanding data and modifying that knowledge. Additionally, a different layered Student Model is presented, which supports adaptive teaching by collecting problem-specific information from student solutions. This research work focuses on learning programming rather than just practicing it. The scenarios presented are intended for expert programming engineers. The paper aims to explore how students learn the Java programming language and how they can securely apply it. It also discusses how students can identify weaknesses in Java applications.

Keywords: Development, Java, Learning, Security, Searching Internet, Students

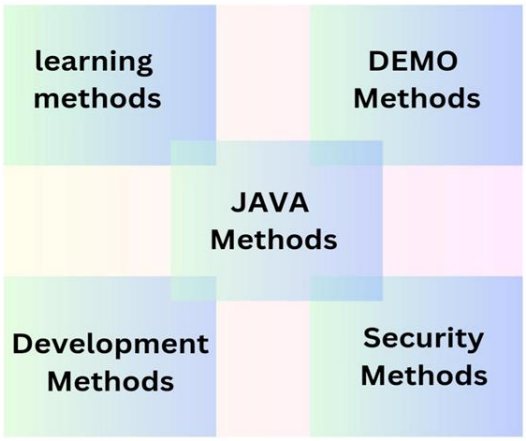
Introduction:

The field of computer programming is complex and can be challenging for many students to grasp due to its abstract nature. Much of the work on data streams can be categorized into two main classes: dynamic, instrumentation-based approaches such as profiling, and static, language-based approaches such as type systems. Despite the variety of languages, frameworks, development environments, and platforms proposed in recent years, implementing Multi-Agent Systems (MAS) remains a daunting task. How can the Java programming language be taught to individuals who are not familiar with programming? I will discuss various Java Learning Language structures for students. Learning is a lifelong process of transforming information and experience into knowledge, attitudes, practices, and behaviours. On the other hand, research in Multi-Agent Systems (MAS) has led to the

development of practical programming languages and tools suitable for implementing such systems.

Methodology

This paper presents a survey of Java methods aimed at novice students. It utilized two online tools for this survey, comprising a total of 18 questions. These tools were instrumental in gathering responses from students and individuals from various countries. The surveys are divided into four sections, each focusing on different aspects of Java programming.



Java Learning Methods: This model outlines a simplified approach to learning the Java programming language, following the standard learning methods. It aims to teach Java to students through teachers or guides, though student motivation for learning Java often does not yield the desired results. The model includes related documentation that describes the structure, purpose, operation, support, and information requirements for Java Programming Language. It emphasizes that coaching also involves significant self-study. Books and tutorials play a crucial role, with tutorials offering intensive tuition by a tutor to an individual student. Searching the internet provides a vast amount of information, but users must be wary of the quality and relevance of the information found online to avoid misinformation (Singh, 2012).

Java Demonstration Method: Demonstration involves presenting information clearly and effectively, often using examples or experiments to explain concepts. In teaching through demonstration, students are prepared to conceptualize class material more effectively, as demonstrated in a study that specifically focuses on the demonstration of Java programming language concepts.

Java Development Method: In software engineering, a software development or framework development methodology is a foundation used to structure, plan, and organize

the process of developing an information system. The Java development methodology is divided into four components. In the e-learning system design, based on previous literature on information systems success, six dimensions of success factors, namely, system quality, information quality, service quality, usability, user satisfaction, and net benefit, are integrated into a comprehensive success model (Singh, 2027).

Java Security Method: In the current era where PC networking plays a crucial role in everyday life, computer criminals pose a threat to critical network environments. Common criminal activities include monitoring network traffic, altering databases, modifying website scripts, disabling services, and data theft. These activities can lead to negative publicity, data loss, and privacy issues, resulting in significant financial damage to companies. Security breaches often result from poor programming practices during development. Some of these security vulnerabilities are easily identified and fixed when the program crashes or unexpected output is generated. I have divided Java security into four parts. E-Learning has attracted significant research and development funding and commercial interest. This has led to the creation of a large body of books, refereed and professional journal articles and reports, and commercial and other web resources that provide monitoring reports and guidance for the development of learning experiences (Singh, 2017).

Result and Discussion:

The survey on the Java programming language and methods of improvisation yielded insightful results. The study revealed that while Java is widely used and appreciated for its versatility and platform independence, novice students often face challenges in grasping its concepts. Methods such as demonstrations, e-learning, and coaching were identified as effective approaches to enhance learning outcomes. Additionally, the importance of security in Java development was highlighted, emphasizing the need for robust programming practices to prevent security breaches. Overall, the survey underscored the importance of adopting innovative teaching methods and ensuring security in Java programming.

Conclusion:

In conclusion, this paper has presented a comprehensive model for students interested in learning the Java Programming Language. The model, consisting of four segments, offers flexibility and choice to students, allowing them to tailor their learning experience to their preferences and goals. The survey conducted to evaluate the

effectiveness of the model showed high agreement among students, indicating its potential to enhance the learning experience. The model includes methods for learning, development, demonstration, and security, providing a holistic approach to Java programming education. It emphasizes the importance of practical application, self-study, and utilizing resources such as books, tutorials, and online resources. Additionally, the model highlights the significance of security in Java development and provides guidelines for securing Java applications and projects. Overall, the model offers a structured and effective approach to learning Java, addressing the diverse needs and learning styles of students. Future research could focus on implementing and evaluating the model in educational settings to further validate its effectiveness and impact on students' learning outcomes.

References:

1. Tejinder Singh1, E. G. (2016). Review M-Learning: Learning Environment Using Android Mobile Application. International Journal of Advanced Technology in Engineering and Science,225-227.
2. Essi Lahtinen, K. A.-M.-M. (2005). A Study of the Difficulties of Novice Programmers. ACM, ITiCSE,14-18.
3. Fang Wei, S. H. (2005). A Student Model For Object-Oriented Design And Programming. Journal of Computing Sciences in Colleges, 20(5), 260-273.
4. Rafael H. Bordini, L. B. (2006). A Survey of Programming Languages and Platforms for Multi-Agent Systems. Informatica, 33-44.
5. Singh, D. T. (2017). Review: A Study Of Essentials Factors For E-Learning. International Journal of Advance Research in Engineering, 31-35.
6. Singh, T. (2012). New Learning Methodology of student of Java Programming Language. International Journal of Engineering Research and Development, 17-19.
7. Singh, T. (2013). New Software Development Methodology for Student of Java Programming Language. International Journal of Computer and Communication Engineering, 194-196.
8. Yin Liu, A. M. (2010). Static Information Flow Analysis with Handling of Implicit Flows and A Study on Effects of Explicit Flows vs Implicit Flows. Software Maintenance and Reengineering (CSMR),2010 14th European Conference (pp. 1-10). Madrid, Spain: IEEE.

A STUDY OF JAVA TESTING FRAMEWORKS

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Abstract:

In recent times, one of the most significant issues in software development has emerged creating software that is resilient and dependable. Software quality can be guaranteed by the testing process, which gathers software-related data. Testing can increase the stability of software, however testing big software projects is difficult because present solutions are usually rigid and expensive. In this study, we present Soft Test, a new scalable and adaptable framework for unique path-based coverage testing in Java application testing. We outline the framework's initial implementation for branch coverage testing and show that our strategy is workable.

Introduction:

The necessity of creating reliable, high-quality software has grown over the past few years. In order to enable quality assurance, testing is a crucial activity that collects data about the software that is being produced or modified. It typically requires a great deal of Labor and Resources, making up between 50 and 60 percent of the entire cost of developing software [3]. Robustness and software quality are becoming more important, which calls for better testing techniques. The dearth of high-quality instruments impedes testing methodologies [4]. The quantity and range of tests that can be run on big programs are restricted by the limitations of the current tools, which are not scalable in terms of memory or time. In order to add instrumentation code for testing, these tools frequently alter the software binary. Never the less, the application's tested version differs from the one that is shipped to Errors and clients might still exist. Most testing tools are inflexible and only support specific testing methods, like different forms of structural testing.

Software applications have permeated various aspects of our lives, including healthcare, transportation, and media. However, the process of software testing remains a costly and time-consuming end during software development [3]. Test frameworks are devised to streamline and simplify software testing procedures. In the realm of Rapid

Application Development (RAD), Framework Oriented Design (FOD) offers valuable patterns for comprehending development systems.

Test Framework Challenges:

Framework provides a software platform by using specific tools and techniques. The test use verification as a method and software program for validation. Software platforms for testing are called test frameworks. Software testing talents and test facilitators should be identified, and testing problems should be addressed with a proposed solution or solutions.

Test Framework:

We are in the process of developing Soft Test, a comprehensive framework tailored for testing Java software. The framework's components, comprising a test specifier, a test planner, a Test Virtual Machine (TVM) and a test Analyzer. A pivotal component is the language, test spec, utilized for specifying the software testing process. This specification encompasses pertinent parts of the program under scrutiny and delineates necessary actions for the testing procedure. Testers have the option to either manually draft a specification in test spec or utilize the GUI, which automatically generates the specification. The test planner consumes the test spec specification and devises a comprehensive plan for testing the program accordingly. Utilizing this plan, the TVM dynamically executing program to execute the specified tests. Thus, the test plan essentially acts as a "program" executed on the TVM to execute various software tests. The TVM is seamlessly integrated into the IBM likes Java RVM. Finally, the framework boasts an Analyzer responsible for presenting test results to the user. In subsequent sections, we delve into the specifics of Soft Test and our branch coverage tool, elucidating test specification, test planning, the TVM, and the test Analyzer.

Test Specification:

When testing software, a developer might want to run multiple tests on different sections of the code. The tests are frequently used with other cover-age criteria. A Graphical User Interface (GUI) in Soft Test allows you to define which tests to run, where to run them, and under what circumstances. The GUI interface of our branch coverage testing tool allows you to choose code regions. For every region, a coverage criterion may also be defined.

Test Planner:

The test planner operates by generating an intermediate representation from the test specification, enabling it to make decisions regarding the instrumentation of a Java program. Specifically, for branch coverage, the test planner is invoked whenever a method is loaded by the Likes Just-in-Time compiler. It assesses whether the loaded method is specified in the test specification, indicating whether it should be instrumented to facilitate branch coverage testing. Consequently, only methods that are actively loaded and executed undergo instrumentation by the planner.

Moreover, the planner retrieves the source code to bytecode line number mapping from a Java class file. If the user has specified certain test regions, the planner identifies the essential basic blocks to be tested and configures the necessary parameters in the test plan. The primary role of the test planner is to delineate where and how to conduct application testing by generating a comprehensive test plan, comprising a test table and an instrumentation payload. The test table outlines the procedures for executing specific tests, particularly for branch coverage, specifying when to insert and remove instrumentation to cover each edge of a method's Control Flow Graph (CFG). The instrumentation payload comprises target machine code executed at each instrumentation point. For branch coverage, this payload code updates a table recording covered edges, removes instrumentation upon coverage, and inserts new instrumentation for yet-to-be-covered edges along the execution path dynamically.

To implement branch coverage testing with minimal overhead, the test planner must strategically determine the optimal instrumentation approach. The overarching objective is to minimize the execution of instrumentation code. when the procedure is executed. According to the plan, instrumentation is inserted dynamically by using a block that is hit place instrumentation in its successors. Predecessors and successors are required to ascertain the edge that was used for branch testing. A method's CFG is constructed by the planner in order to obtain this data.

Test Virtual Machine:

Leveraging insights from the test planner, the TVM facilitates the dynamic insertion and removal of instrumentation during runtime. Operating on target machine code generated by the Likes JIT compiler, the TVM interfaces with fast breakpoints to implement instrumentation. These breakpoints efficiently replace instructions in the target machine

code with a jump to a breakpoint handler, invoking the test instrumentation payload specified by the test planner.

In the branch coverage prototype, the TVM initiates a breakpoint at the initial point designated by the test plan. This singular breakpoint orchestrates the placement of subsequent breakpoints, targeting the successor basic blocks identified by the planner for branch coverage. As execution progresses, the payload code executed by these breakpoints dynamically establishes additional breakpoints in successor blocks. This strategic approach minimizes the impact on program execution, ensuring that instrumentation is predominantly applied along the currently executing path. Consequently, performance is minimally affected, particularly benefiting hot paths and tight loops where instrumentation is selectively applied for a limited number of iterations. Consequently, the majority of execution time is dedicated to running code without instrumentation.

The TVM's API offers primitives for tasks such as placing successor breakpoints, storing test-specific data, and removing breakpoints. This versatility in instrumentation construction allows for various specifications, ensuring scalability by instrumenting only relevant program portions for the required duration.

Test Analyzer:

The test Analyzer within the Soft Test framework serves to present the outcomes of tests conducted. For branch coverage, the Analyzer visualizes the Control Flow Graph (CFG) for a method, highlighting the edges covered by a specific test input. Currently, the prototype displays the CFG for the target machine code, with plans to incorporate support for source-level coverage as well.

Conclusion:

In summary, our study addresses the pressing issue of ensuring software resilience and dependability through robust testing methodologies. While acknowledging the vital role of testing in improving software quality, we recognize the limitations of current approaches, often constrained by inflexibility and high costs, particularly in large-scale projects.

Our research introduces Soft Test, a pioneering framework designed to overcome these challenges by offering scalability and adaptability for comprehensive path-based coverage testing in Java applications. Our initial implementation, focusing on branch coverage testing, validates the feasibility and efficacy of our approach.

Soft Test represents a significant advancement in software testing, providing developers with a flexible and cost-effective solution to address the intricacies of modern software projects. By prioritizing scalability and adaptability, we believe Soft Test has the potential to transform testing practices, ultimately leading to the development of more resilient and reliable software systems.

References:

1. Shahamiri, S.R., Kadir, W.M.W.K., Ibrahim, S., Hashim, S.ZM. (2011). An automated framework for software test oracle. Information and Software Technology 53. 774 788. DOI: 10.1016/j.infsof.2011.02.006
2. Shamsoddin-Motlagh, E. (2012). A Survey of Service Oriented Architecture Systems Testing. International Journal of Software Engineering & Applications (IJSEA), Vol.3, No.6, November 2012. 19-27. DOI: 10.5121/ijsea.2012.3602
3. Wahid, M., Almalaise. A. (2011). JUnit Framework: An Interactive Approach for Basic Unit Testing Learning in Software Engineering. 3rd International Congress on Engineering Education (ICEED). 159-164. DOI: 10.1109/ICEED.2011.6235381
4. Wang, B., Zhu, C., Sheng. (2010). MDA-Based Automated Generation Method of Test Cases and Supporting Framework. 2nd International Conference on Computer Engineering and Technology (ICCET). 106 109. DOI: 10.1109/ICCET.2010.5486276
5. Xu-Xiang, L., Wen-Ning, Z. (2010). THE PDCA BASED SOFTWARE TESTING IMPROVEMENT FRAMEWORK. International Conference on Apperceiving Computing and Intelligence Analysis (ICACIA). 490-494. 10.1109/ICACIA.2010.5709948 DOI
6. Chu, H.D. (2012). A Blackboard-based Decision Support Framework for Testing Client/Server Applications. Third World Congress on Software Engineering. 131-135. DOI 10.1109/WCSE.2012.31
7. Asif, M., Reddy. Y.R. (2013). JIFFY A Framework for Encompassing Aspects in Testing and Debugging Software. AST 2013, San Francisco, CA, USA. 146-149. DOI: 10.1109/IWAST.2013.6595806

CONVERGENCE OF CUTTING-EDGE TECHNOLOGIES: INNOVATIONS IN GENETIC ENGINEERING, BIOTECHNOLOGY, AI, AND QUANTUM COMPUTING

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Abstract:

To tackle complex scientific and societal issues in this era of rapid technological innovation, it is essential to integrate innovative research disciplines. The groundbreaking impacts of several modern disciplines are covered in this chapter, including genetic engineering, nanotechnology, biotechnology, artificial intelligence, machine learning, and quantum computing. We examine the symbiotic ties between these domains to show how they can revolutionise science and technology when combined. The fields of agriculture, health, and environmental sustainability are being transformed by genetic engineering and biotechnology, which enable precise genome editing, biofortification, and the manufacturing of biopharmaceuticals. Nanotechnology offers the ability to enhance these efforts in various ways, including drug delivery, biosensing, and enhanced materials. Simultaneously, AI and ML are automating formerly manual operations across all industries, improving prediction accuracy, and transforming data analysis. Quantum computing may solve computationally intractable problems, opening up new possibilities in optimisation, cryptography, and the discovery of novel materials. However, the technology is still in its early phases. The potential of these interdisciplinary advancements to inspire new ideas, solve pressing global problems, and lay the framework for a sustainable and technologically empowered future is explored in detail in this chapter.

Introduction:

The ever-evolving fields of science and technology are the bedrock of modern civilization, driving transformative changes across industries and society. From artificial intelligence to quantum computing, innovative research trends are pushing the boundaries of human knowledge and capabilities, addressing critical challenges such as climate change, global health crises, and resource sustainability. These trends not only enable

groundbreaking discoveries but also foster interdisciplinary collaboration, ensuring that advancements in one domain amplify progress in others. Over the past decade, several paradigm shifts have emerged, fueled by rapid advancements in computational power, biotechnology, and material science. Artificial intelligence has evolved from a niche academic pursuit to a cornerstone of global innovation, powering solutions in fields ranging from healthcare to finance. Similarly, genetic engineering breakthroughs, such as CRISPR-Cas9, have redefined our ability to address diseases and enhance agricultural productivity. Quantum computing, once a theoretical construct, is now poised to revolutionize industries through its unparalleled computational capabilities.

The convergence of diverse scientific disciplines has also led to significant strides in addressing sustainability. Renewable energy technologies are becoming more efficient and accessible, contributing to the global fight against climate change. Nanotechnology, with its promise of precision at the atomic scale, is delivering breakthroughs in medicine, electronics, and environmental remediation. Space exploration, once dominated by government agencies, is now a frontier for commercial enterprises, paving the way for interplanetary habitation and resource utilization. This chapter explores these innovative research trends in detail, providing insights into their key advancements, practical applications, and potential societal impacts. By examining areas such as artificial intelligence, biotechnology, renewable energy, quantum computing, nanotechnology, and space exploration, this work aims to highlight the transformative potential of modern science and technology. Each section delves into the fundamental innovations driving these fields, their real-world applications, and the ethical and social considerations that must accompany their adoption. Together, these trends illustrate a future where science and technology serve as powerful catalysts for human progress, fostering a more sustainable, equitable, and interconnected world.

Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) have revolutionized the way we approach problem-solving, decision-making, and automation across numerous sectors. AI, the broader concept of creating systems capable of performing tasks that typically require human intelligence, is powered by ML—a subset of AI that enables systems to learn from data and improve over time without explicit programming. This section explores the fundamental innovations, applications, and challenges of AI and ML.

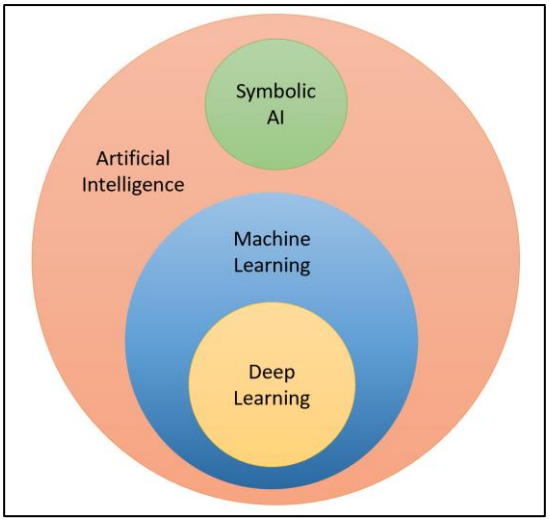

Fig. 1: Aspects of AI with its fields

1. Applications:

Healthcare

- **Diagnostics:** AI-powered tools analyze medical images to detect diseases like cancer and diabetic retinopathy with high accuracy (Esteva *et al.,* 2017).
- **Drug Discovery:** AI accelerates the identification of drug candidates by simulating molecular interactions and predicting efficacy (Zhavoronkov *et al.,* 2020).

Industry and Automation

- **Predictive Maintenance:** ML models predict equipment failures, reducing downtime and maintenance costs in manufacturing (Kumar *et al.,* 2019).
- **Robotics:** AI-driven robots perform tasks in hazardous environments, such as deep-sea exploration and disaster recovery.
- **Supply Chain Optimization:** AI optimizes logistics, inventory management, and demand forecasting, enhancing operational efficiency.

Finance and Business

- **Fraud Detection:** ML algorithms detect anomalies in transaction patterns, mitigating financial fraud (Ngai *et al.,* 2011).
- **Customer Insights:** AI analyzes consumer behavior to personalize marketing strategies and improve customer experiences.

Education and Research

- **Adaptive Learning Platforms:** AI-powered tools create personalized learning experiences based on students' progress and preferences.

- **Research Acceleration:** ML algorithms analyze vast datasets to identify trends and generate hypotheses, aiding scientific discoveries.

Environment and Sustainability

- **Climate Modeling:** AI improves the accuracy of climate predictions and helps design effective mitigation strategies (Rolnick *et al.,* 2019).
- **Smart Agriculture:** ML-driven systems optimize irrigation, pest control, and crop monitoring to enhance yield and sustainability.

2. Recent Developments

Generative AI

- **Transformers and Diffusion Models**: Advances in generative AI have led to the creation of sophisticated text-to-image systems (e.g., DALL-E) and large language models (Brown *et al.,* 2020).
- **Creative Applications**: AI is now used in content generation, from writing and art to music composition.

Explainable AI (XAI)

- **Transparency in Decision-Making**: XAI tools provide insights into how models make predictions, crucial for sectors like healthcare and finance.

Federated Learning

- **Privacy-Preserving AI**:
    - Federated learning allows models to be trained across decentralized devices while keeping data local, enhancing privacy (McMahan *et al.,* 2017).

AI in Climate Action

- **Predictive Models**: AI forecasts extreme weather events, aiding disaster preparedness and mitigation.
- **Carbon Capture Optimization**: ML models improve the efficiency of carbon capture technologies, crucial for combating climate change.

AI in Quantum Computing

- AI accelerates quantum algorithms' development, enabling faster problem-solving in optimization, cryptography, and material science (Biamonte *et al.,* 2017).

3. Future Directions

The future of AI lies in the development of more explainable and generalizable models, ensuring transparency and adaptability across diverse domains. Research into hybrid AI systems, combining symbolic reasoning with deep learning, aims to create more

robust and interpretable solutions. Advancements in quantum computing hold the potential to further accelerate AI capabilities, enabling breakthroughs in optimization and simulation tasks (Biamonte *et al.,* 2017). Moreover, fostering interdisciplinary collaboration and ethical AI governance will be crucial to maximizing the benefits of AI while mitigating its risks.

Biotechnology and Genetic Engineering

Biotechnology and genetic engineering are transformative fields that leverage biological systems and molecular tools to solve challenges in medicine, agriculture, industry, and environmental management. While biotechnology encompasses the use of living organisms and biological processes for practical applications, genetic engineering specifically refers to the direct manipulation of an organism's DNA to alter its characteristics. Recent advancements have significantly accelerated progress in these fields, leading to breakthroughs that are reshaping science and society.

1. Foundational Principles

Biotechnology Tools:

- **Recombinant DNA Technology**: Combines genetic material from different sources to create novel sequences (Cohen *et al.,* 1973).
- **CRISPR-Cas9**: A revolutionary gene-editing tool that allows precise alterations to DNA (Jinek *et al.,* 2012).
- **Synthetic Biology**: The design and construction of new biological parts and systems (Cameron *et al.,* 2014).

Genetic Engineering:

- **Gene Editing**: Tools like CRISPR, TALENs, and ZFNs enable targeted modifications.
- **Gene Therapy**: Introduces or alters genes within an individual's cells to treat diseases (Naldini, 2015).
- **Transgenic Organisms**: Organisms with genes from other species, commonly used in agriculture and research (Kumar *et al.,* 2020).

2. Applications of Biotechnology and Genetic Engineering

Medicine

- **Personalized Medicine**: Genetic engineering enables tailoring treatments to individual genetic profiles. Advances in pharmacogenomics predict patient responses to drugs (Hood & Friend, 2011).

- **Gene Therapy**: Approval of therapies like Zolgensma for spinal muscular atrophy and Luxturna for retinal dystrophy highlights the success of genetic treatments (Mendell *et al.,* 2017).
- **mRNA Vaccines**: The COVID-19 pandemic demonstrated the power of biotechnology with rapid development of mRNA vaccines by Moderna and Pfizer-BioNTech (Polack *et al.,* 2020)

Agriculture

- **Genetically Modified Crops (GMOs)**: Crops like Bt cotton and Golden Rice have been engineered for pest resistance and nutritional enhancement (Ye *et al.,* 2000).
- **CRISPR in Agriculture**: Gene editing is being used to develop drought-resistant crops and improve yields (Zhang *et al.,* 2019).
- **Synthetic Biology for Fertilizers**: Engineering microbes to fix atmospheric nitrogen as a sustainable alternative to chemical fertilizers (Temme *et al.,* 2012).

3. Recent Developments

Advances in Gene Editing

- **Prime Editing**: An improved version of CRISPR, capable of making precise insertions, deletions, and base swaps without double-stranded breaks (Anzalone *et al.,* 2019).
- **Base Editing**:
    1. Converts single DNA bases (e.g., C-to-T or A-to-G) without inducing double-stranded breaks (Gaudelli *et al.,* 2017).

Synthetic Biology

- **Cell-Free Systems**: Enables biological reactions outside living cells, facilitating rapid prototyping of genetic circuits (Silverman *et al.,* 2020).
- **Xeno-nucleic Acids (XNAs)**: Synthetic alternatives to DNA and RNA that expand the genetic code (Pinheiro *et al.,* 2012).

Bioprinting

- 3D bioprinting of tissues and organs using stem cells and bio-inks offers hope for organ transplantation (Murphy & Atala, 2014).

Omics Technologies

- Advances in genomics, proteomics, and metabolomics are providing insights into complex biological systems and disease mechanisms (Venter *et al.,* 2001).

Bioinformatics and AI

- Machine learning is accelerating gene discovery and protein engineering (Senior *et al.,* 2020).
- AI-powered tools like AlphaFold have revolutionized protein structure prediction (Jumper *et al.,* 2021).

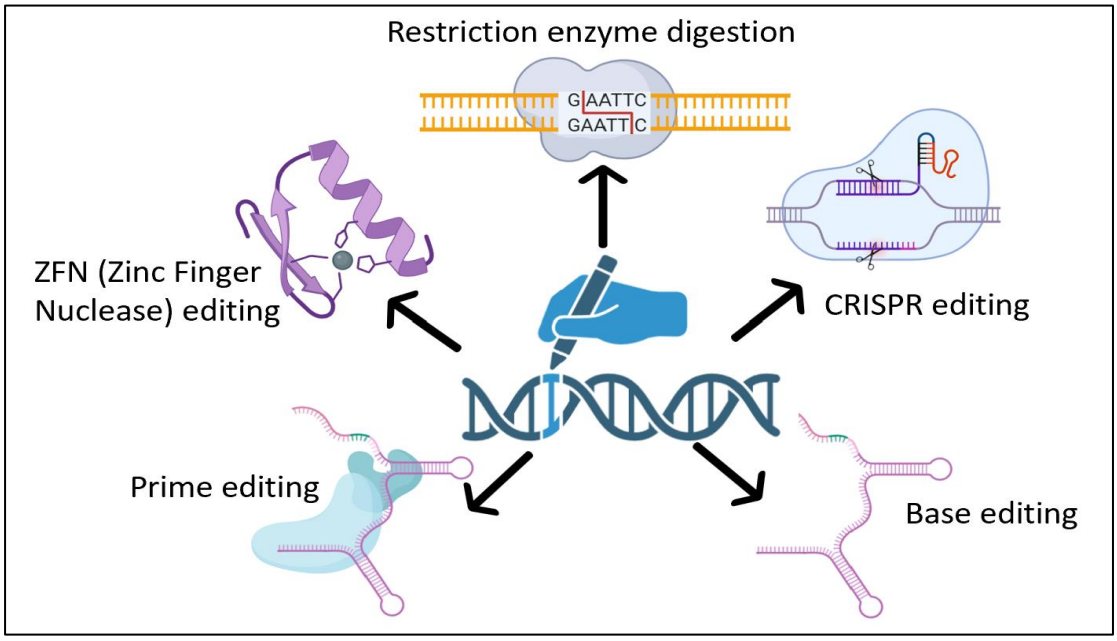

Fig. 2: Different techniques of genetic engineering

4. Ethical and Regulatory Challenges

- **Ethical Concerns**: Human germline editing raises questions about "designer babies" and unforeseen consequences (Gyngell *et al.,* 2019).
- **Access and Equity**: Ensuring that biotechnological advancements are accessible to all, especially in low-income regions.
- **Biosafety and Biosecurity**: Risks associated with genetically engineered organisms escaping into natural ecosystems (Kuiken *et al.,* 2014).

5. Future Directions

The future of renewable energy lies in enhanced efficiency, integration, and innovation. Artificial intelligence and machine learning are being employed to optimize energy production, predict maintenance needs, and balance grid operations. Hybrid renewable energy systems, combining solar, wind, and storage, offer a more resilient and consistent energy supply. Moreover, advancements in materials science, such as quantum dot solar cells and graphene-based batteries, promise to revolutionize renewable energy technologies.

Quantum Computing

Quantum computing represents a paradigm shift in computational technology, leveraging the principles of quantum mechanics to process information. Unlike classical computers, which use bits to represent data as 0s or 1s, quantum computers use quantum bits or qubits. Qubits can exist in a superposition of states, enabling quantum computers to perform complex calculations far more efficiently than their classical counterparts in specific domains.

1. Principles of Quantum Computing

- **Superposition**

Superposition allows qubits to be in multiple states simultaneously. This property enables quantum computers to perform parallel computations. For example, a classical computer evaluating a problem with four possibilities would need to check each one sequentially, while a quantum computer can consider all possibilities simultaneously.

- **Entanglement**

Quantum entanglement is a phenomenon where qubits become interconnected such that the state of one qubit instantly influences the state of another, regardless of distance. This correlation can be harnessed to increase computational power and enable secure communication protocols like quantum cryptography.

- **Quantum Interference**

Quantum interference is used to amplify the probability of correct outcomes and cancel out incorrect ones. Algorithms such as Shor's algorithm for factoring large numbers and Grover's algorithm for database searching rely on this principle.

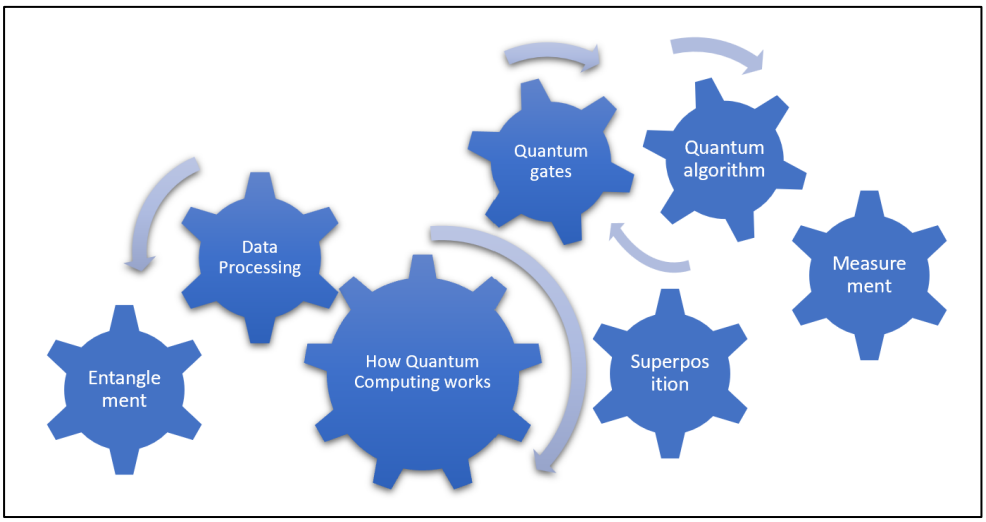

Fig. 3: Principles of Quantum computing and its way of action

2. Advantages of Quantum Computing

- **Speed**: Quantum computers can solve certain problems exponentially faster than classical computers. For example, factoring large integers, a basis for modern cryptography, can be done efficiently using quantum algorithms.
- **Efficiency**: Quantum computers can simulate quantum systems effectively, making them invaluable for research in chemistry, material science, and drug discovery.
- **Optimization**: Problems in logistics, financial modeling, and machine learning often involve finding optimal solutions in vast solution spaces. Quantum computing offers significant advantages in these areas.

3. Challenges in Quantum Computing

- **Decoherence**: Qubits are extremely sensitive to their environment, leading to loss of quantum information through decoherence.
- **Error Correction**: Quantum error correction is more complex than classical error correction due to the probabilistic nature of quantum states.
- **Scalability**: Building and maintaining a large number of qubits that interact coherently is a significant technical challenge.
- **Resource Requirements**: Quantum systems often require extremely low temperatures and precise calibration, making them resource-intensive.

4. Applications of Quantum Computing

- **Cryptography:** Quantum computers pose a threat to classical encryption methods by efficiently solving problems like integer factorization (Shor's algorithm). Simultaneously, they enable quantum key distribution (QKD), a method for ultra-secure communication.
- **Drug Discovery and Material Science:** Quantum computers can simulate molecular structures and interactions at the quantum level, accelerating drug discovery and the development of new materials.
- **Artificial Intelligence and Machine Learning:** Quantum machine learning algorithms promise faster training times and the ability to handle massive datasets more efficiently.
- **Optimization Problems:** Industries such as logistics, finance, and energy benefit from quantum algorithms that solve complex optimization problems more effectively than classical methods.

5. Future of Quantum Computing

Despite its challenges, quantum computing is advancing rapidly. Companies like IBM, Google, and Microsoft, alongside startups and academic institutions, are investing heavily in quantum research. Milestones such as Google's achievement of "quantum supremacy" in 2019—where their quantum computer performed a task infeasible for classical systems—highlight the potential of this technology. Efforts to develop fault-tolerant quantum computers and improve quantum error correction are underway. Additionally, hybrid approaches combining classical and quantum computing are emerging as practical solutions in the near term.

Nanotechnology: An Overview and Recent Developments

Nanotechnology involves the manipulation and utilization of materials at the nanoscale, typically between 1 to 100 nanometers. At this scale, materials exhibit unique properties—such as altered electrical conductivity, reactivity, and mechanical strength—which enable groundbreaking applications across diverse fields like medicine, electronics, energy, and environmental science. In recent years, nanotechnology has witnessed transformative advancements, driven by interdisciplinary research and technological innovation.

1. Applications of Nanotechnology

Medicine and Healthcare

- **Drug Delivery Systems**: Nanocarriers like liposomes, dendrimers, and polymeric nanoparticles enhance targeted drug delivery, minimizing side effects (Allen & Cullis, 2004). Recent developments include nanoparticle-based mRNA delivery systems for vaccines (Hou *et al.,* 2021).
- **Diagnostics and Imaging**: Quantum dots and nanosensors provide high-resolution imaging and early detection of diseases (Bruchez *et al.,* 1998).
- **Cancer Therapy**: Gold nanoparticles and nanoshells are used for photothermal therapy, targeting tumor cells with precision (Huang *et al.,* 2006).

Electronics and Information Technology

- **Miniaturized Devices**: Advances in nanolithography enable smaller and more efficient transistors, powering modern microprocessors (Schwierz, 2010).
- **Flexible Electronics**: Nanomaterials like graphene and carbon nanotubes are used in wearable and bendable devices.

- **Quantum Computing**: Quantum dots and nanowires form the basis of qubits, crucial for quantum information processing (Loss & DiVincenzo, 1998).

Energy and Environment

- **Solar Energy**: Perovskite nanomaterials enhance the efficiency of solar cells, achieving power conversion efficiencies over 25% (Green *et al.,* 2020).
- **Batteries and Supercapacitors**: Nanostructured electrodes improve energy density and charge/discharge rates in lithium-ion batteries (Bruce *et al.,* 2011).
- **Environmental Remediation**: Nanoparticles like titanium dioxide and zero-valent iron are used for pollutant degradation and water purification (Zhang *et al.,* 2003).

Agriculture and Food

- **Smart Delivery Systems**: Nanofertilizers and nanopesticides optimize the release of nutrients and active ingredients, reducing environmental impact (Kah *et al.,* 2018).
- **Food Packaging**: Nanocomposite films with antimicrobial properties enhance food preservation and safety (Chaudhry *et al.,* 2008).

2. Recent Developments

Graphene Applications

- Graphene's remarkable electrical and mechanical properties have led to innovations in flexible electronics, water filtration membranes, and advanced composites (Novoselov *et al.,* 2004).

Nanomedicine

- The development of nanostructured lipid carriers for mRNA vaccines, as demonstrated during the COVID-19 pandemic, highlights the potential of nanotechnology in combating infectious diseases (Sahin *et al.,* 2020).
- Nanoscale biosensors are being integrated into wearable devices for real-time health monitoring.

Sustainable Nanotechnology

- **Green Synthesis**: Researchers are focusing on eco-friendly methods for synthesizing nanoparticles using plant extracts and microorganisms (Iravani, 2011).
- **Circular Economy**: Recycling and reusing nanomaterials in industrial processes aim to minimize waste and resource consumption.

Nanorobotics

- Advances in nanorobotics have led to the development of nanoscale machines capable of performing tasks like targeted drug delivery and micro-surgery (Martel *et al.,* 2014).

3D Nanoprinting

- Nanoscale 3D printing techniques are enabling the fabrication of complex structures for applications in tissue engineering and microelectronics (Farsari & Chichkov, 2009).

3. Ethical and Safety Considerations

- **Toxicity and Health Risks**: Nanoparticles can penetrate biological membranes, potentially causing adverse health effects (Nel *et al.,* 2006).
- **Environmental Impact**: The persistence of engineered nanoparticles in ecosystems raises concerns about long-term effects on biodiversity and soil health.
- **Regulation and Public Perception**: Developing standardized frameworks for testing and regulating nanotechnology applications is critical for public trust and safety.

4. Future of Nanotechnology

Nanotechnology continues to revolutionize diverse fields, offering solutions to some of the world's most pressing challenges. However, its responsible development necessitates a balanced approach, integrating innovation with ethical and environmental considerations. Future advancements, particularly in nanomedicine, quantum devices, and sustainable technologies, promise to redefine the boundaries of human capability.

Conclusion:

Innovative research trends in science and technology are redefining the paradigms of progress, offering novel solutions to the world's most pressing challenges. Fields like Artificial Intelligence, Machine Learning, Biotechnology, and Genetic Engineering exemplify the convergence of scientific creativity and technological prowess. As these disciplines advance, they promise not only to enhance human well-being but also to foster sustainable development and global collaboration. To fully realize the potential of these innovations, a commitment to ethical frameworks, public engagement, and interdisciplinary partnerships will be essential. The future of science and technology is boundless, driven by a relentless quest for knowledge and a shared vision for a better tomorrow.

References:

1. Biamonte, J., Wittek, P., Pancotti, N., Rebentrost, P., Wiebe, N., and Lloyd, S. (2017). Quantum machine learning. *Nature*, 549(7671):195-202.
2. Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J. D., Dhariwal, P. and Amodei, D. (2020). Language models are few-shot learners. *Advances in neural information processing systems*, 33: 1877-1901.
3. Buolamwini, J. and Gebru, T. (2018). Gender shades: Intersectional accuracy disparities in commercial gender classification. In *Conference on fairness, accountability and transparency* (pp. 77-91).
4. Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *nature*, *542*(7639): 115-118.
5. McMahan, B., Moore, E., Ramage, D., Hampson, S. and Arcas, B. A. (2017). Communication-efficient learning of deep networks from decentralized data. In *Artificial intelligence and statistics*, 1273-1282.
6. Ngai, E. W., Hu, Y., Wong, Y. H., Chen, Y., and Sun, X. (2011). The application of data mining techniques in financial fraud detection: A classification framework and an academic review of literature. *Decision support systems*, 50(3): 559-569.
7. Stokes, J. M., Yang, K., Swanson, K., Jin, W., Cubillos-Ruiz, A., Donghia, N. M. and Collins, J. J. (2020). A deep learning approach to antibiotic discovery. *Cell*, 180(4): 688-702.
8. Anzalone, A. V., Randolph, P. B., Davis, J. R., Sousa, A. A., Koblan, L. W., Levy, J. M. and Liu, D. R. (2019). Search-and-replace genome editing without double-strand breaks or donor DNA. *Nature*, 576(7785): 149-157.
9. Cameron, D. E., Bashor, C. J. and Collins, J. J. (2014). A brief history of synthetic biology. *Nature Reviews Microbiology*, 12(5): 381-390.
10. Chen, G. Q. (2012). New challenges and opportunities for industrial biotechnology. *Biotechnology Advances,* 30(5): 1255-1266.
11. Gaudelli, N. M., Komor, A. C., Rees, H. A., Packer, M. S., Badran, A. H., Bryson, D. I. and Liu, D. R. (2017). Programmable base editing of A• T to G• C in genomic DNA without DNA cleavage. *Nature*, 551(7681): 464-471.
12. Hood, L. and Friend, S. H. (2011). Predictive, personalized, preventive, participatory (P4) cancer medicine. *Nature Reviews Clinical Oncology,* 8(3): 184-187.

13. Jumper, J., Evans, R., Pritzel, A., Green, T., Figurnov, M., Ronneberger, O. and Hassabis, D. (2021). Highly accurate protein structure prediction with AlphaFold. *nature*, 596(7873): 583-589.
14. Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J. A. and Charpentier, E. (2012). A programmable dual-RNA–guided DNA endonuclease in adaptive bacterial immunity. *science*, 337(6096): 816-821.
15. Kumar, S. (2020). Transgenic crops: Current status and future challenges. *Plant Biotechnology Journal,* 18(3): 865-885.
16. Murphy, S. V. and Atala, A. (2014). 3D bioprinting of tissues and organs. *Nature Biotechnology,* 32(8): 773-785.
17. Naldini, L. (2015). Gene therapy returns to centre stage. *Nature,* 526(7573): 351-360.
18. Polack, F. P., Thomas, S. J., Kitchin, N., Absalon, J., Gurtman, A., Lockhart, S. and Gruber, W. C. (2020). Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. *New England journal of medicine*, 383(27): 2603-2615.
19. Silverman, A. D., Karim, A. S. and Jewett, M. C. (2020). Cell-free gene expression: an expanded repertoire of applications. *Nature Reviews Genetics*, 21(3): 151-170.
20. Venter, J. C., Adams, M. D., Myers, E. W., Li, P. W., Mural, R. J., Sutton, G. G. and Kalush, F. (2001). The sequence of the human genome. *science*, 291(5507):1304-1351.
21. Nielsen, M. A. and Chuang, I. L. (2010). *Quantum Computation and Quantum Information*. Cambridge University Press.
22. Preskill, J. (2018). Quantum Computing in the NISQ era and beyond. *Quantum*, 2, 79.
23. Arute, F., Arya, K. and Babbush, R. (2019). Quantum supremacy using a programmable superconducting processor. *Nature*, 574: 505–510.
24. Shor, P. W. (1994). Algorithms for quantum computation: Discrete logarithms and factoring. *Proceedings 35th Annual Symposium on Foundations of Computer Science*.
25. Grover, L. K. (1996). A fast quantum mechanical algorithm for database search. *Proceedings of the Twenty-Eighth Annual ACM Symposium on Theory of Computing*.
26. Allen, T. M. and Cullis, P. R. (2004). Drug delivery systems: Entering the mainstream. *Science, 303*(5665): 1818-1822.
27. Bruchez Jr, M., Moronne, M., Gin, P., Weiss, S., & Alivisatos, A. P. (1998). Semiconductor nanocrystals as fluorescent biological labels. *science*, 281(5385): 2013-2016.

28. Bruce, P. G., Scrosati, B. and Tarascon, J. M. (2008). Nanomaterials for rechargeable lithium batteries. *Angewandte Chemie International Edition*, 47(16), 2930-2946.
29. Green, M. A. (2020). Solar cell efficiency tables (Version 55). *Progress in Photovoltaics: Research and Applications,* 28(3), 629-638.
30. Kah, M., Beulke, S., Tiede, K. and Hofmann, T. (2013). Nanopesticides: state of knowledge, environmental fate, and exposure modeling. *Critical Reviews in Environmental Science and Technology*, 43(16): 1823-1867.
31. Sahin, U., Muik, A., Derhovanessian, E., Vogler, I., Kranz, L. M., Vormehr, M. and Türeci, Ö. (2020). COVID-19 vaccine BNT162b1 elicits human antibody and TH1 T cell responses. *Nature*, 586(7830): 594-599.
32. Zhang, W. X. (2003). Nanoscale iron particles for environmental remediation: An overview. *Journal of Nanoparticle Research,* 5(3): 323-332.

REVIEW ON A NUMBER OF WASTEWATER TREATMENT METHODS OF PETROLEUM INDUSTRIES

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Abstract:

This paper presents a review of techniques in wastewater management and a discussion as to how they can be integrated in future water management issues. Water is one of the most important natural resources for life to exist. Its growth and control are critical to human survival. In the petroleum industry, polluted water is typically generated during various production or processing procedures. Liquid leaks from manufacturing process, storage, or pipes to the ground can also pollute subsurface water. As a result, we face various issues in the water sector, including decreased per capita water supply, groundwater table fall in many locations, and saltwater intrusion in coastal aquifers. Because of increased pollution loads from diverse sources, the quality of surface water and groundwater is also decreasing. These contaminants may include various parameters such as chemical oxygen demand (COD), biological oxygen demand (BOD), ammonia, phenols, sulphides, oil and grease, etc. The amount of oxidation that will occur organic materials and the number of inorganic compounds in a sample are determined by chemical oxygen demand testing. Petroleum wastewater treatment can be done using three different methods such as physical, chemical, and biological. Pre-treatment, which comprised mechanical and physicochemical treatments is the first stage, followed by advanced treatment of the pretreated wastewater in the second. Physical treatment procedures are those that enhance or treat wastewater solely through physical phenomena rather than large chemical or biological changes. Two examples include coarse screening to remove bigger entrained objects and sedimentation. Chemical treatment is the process of improving the quality of water by using a chemical reaction or a series of chemical reactions. Microorganisms, especially bacteria, are used in the biochemical breakdown of wastewaters to stable end products. There are other processes which may or may not include combination of two treatment process such as membrane separation,

coagulation/flocculation and electrocoagulation. Adsorption, Physicochemical treatment, anaerobic biological process, aerated lagoons, activated sludge process, biofilm-based reactor etc. This study provides an outline of seven methods related to wastewater development in the petroleum industries. These methods include precipitation using chemicals containing Fe^{2+} and Fe^{3+}, Up-flow anaerobic sludge bed (UASB), Polyvinylidene fluoride (PVDF) nanocomposite membranes with different fillers, Immersed membrane technique, Microwave (MW)-assisted catalytic wet air oxidation (CWAO) method, TiO_2/Fenton ($TiO_2/H_2O_2/Fe^{2+}$/sunlight) solar photo-catalyst in the advanced oxidation process (AOP) and electrocoagulation. The pollutants removed in these processes were sulphide, COD (chemical oxygen demand), Total organic carbon (TOC), Oil, and Phenol.

Keywords: Wastewater Treatment; Petroleum Industry; Chemical Oxygen Demand(COD); Up-Flow Anaerobic Sludge Bed (UASB); Catalytic Wet Air Oxidation (CWAO); Total Organic Carbon(TOC).

Introduction:

Petroleum refining is one of the world's largest industries and an important aspect of any country's economy. Water is almost as vital as oil in the oil business. Oil Industries have to deal with more water than oil. This is due to the fact that enormous amounts of water are required for many of the essential activities. Fresh water is used in a variety of industries, from production and manufacturing to steam and power generation. Seawater is also employed in cooling systems and to keep oil reservoirs under pressure. However, they do not simply throw away the water they use. After cleaning, they return the majority of it to the environment. In locations where oil firms operate, there are often competing demands on water resources: access to clean fresh water may be limited, available supplies may be overstretched, and, in the worst circumstances, pollution may have rendered certain natural water resources useless. The oil business is dedicated to achieving a healthy balance between agricultural, local communities, and commerce's water needs(Chevrontexaco, 2005).On the other hand, potential environmental hazards linked with refineries, have raised concerns among communities near them. This update gives a summary of the processes involved, as well as some of the environmental risks connected with petroleum refineries relating to its water management. Petroleum refineries use a variety of physical and chemical separation procedures to extract crude oil into a variety of petroleum products. Fractionation, cracking, hydrotreating, combination/blending procedures, manufacturing, and transportation are some of the techniques used. Petroleum gas, kerosene, diesel fuel, motor oil, asphalt, and waxes are some of the goods produced by

the refining sector(Hazardous Substance Research Center, 2003).The objective of this review is to study appropriate water resource management options for wastewater reuse and to improve the quality of the reclaimed water and enable its recycling.

Discussion:

Processes involved in refining crude oil

Separation and blending of petroleum products involve a series of steps in oil refining. Below is a basic description of the five major processes(Requirements & Selected, 1963):

a) Separation processes: The numerous fractions/hydrocarbon molecules that make up crude oil are separated based on their boiling point differences in these methods. Crude oil is made up of all of the components that go into making gasoline, diesel, oils, and waxes. Atmospheric and vacuum distillation are common methods for separation. On order to make finished products that can be sold in the market, these fractions frequently require additional processing.

b) Conversion processes: Cracking, reforming, coking, and visbreaking are conversion processes that use heat or catalysts to break down large longer chain molecules into smaller ones. These operations enable refineries to break down heavier oil fractions into lighter fractions, allowing them to raise the fraction of higher demand components like gasoline, diesel fuels, or whatever else is more helpful at the time.

c) Treating: Unwanted components and contaminants like as sulphur, nitrogen, and heavy metals are removed from goods via petroleum-treating procedures. Hydrotreating, deasphalting, acid gas removal, desalting, hydrodesulfurization, and sweetening are some of the procedures involved.

d) Blending/combination processes: Blending/combination operations are used in refineries to make mixtures with diverse petroleum fractions in order to produce a desired final product. Combining different combinations of hydrocarbon chains to generate lubricating lubricants, asphalt, or gasoline with varied octane ratings is an example of this procedure.

e) Auxiliary processes: In addition to supplying power, waste treatment, and other utility services, refineries have various processes and units that are critical to their operations. These facilities' products are frequently recycled and used in other refinery processes, and they're also vital for reducing water and air pollution. Boilers, wastewater treatment, and cooling towers are examples of these devices.

Water pollution hazards of petroleum refineries and treatment methods

Refineries are a major source of contamination in both ground and surface water (Raimi *et al.,* 2022). Some refineries utilize deep-injection wells to dispose of wastewater created within their facilities, and some of these pollutants wind up in aquifers and groundwater. Given the number of sources it can come into contact with during the refining process, wastewater in refineries may be extremely polluted from sources such as equipment leaks and spills and the desalting of crude oil. This polluted water could be desalination waste, cooling tower water, storm water, distillation waste, or cracking waste. It could contain oil residues as well as a variety of other hazardous contaminants. During the refining process, this water is recycled multiple times and then treated, including at a wastewater treatment plant, before being released into surface waters. Sulfides, ammonia, suspended particles, and other chemicals that may be present in wastewater are limited by these discharge standards. Despite the fact that these limits are in place, considerable contamination from previous discharges may still be present in surface water bodies.

Physical, chemical, and biological treatments are the three forms of petroleum wastewater treatment. Traditional treatment procedures necessitate a multistage process. The first stage consists of pre-treatment, which included mechanical and physicochemical treatments, followed by advanced treatment of the pretreated wastewater in the second stages. Physical treatment methods are those that use only physical phenomena to enhance or treat wastewater rather without making any major chemical or biological changes. Coarse screening to remove larger entrained items and sedimentation are two examples (Altas, 2008). So, the physical treatment system is an important first stage in the treatment process, as it removes or separates suspended solids, immiscible liquids, and solid particles. Chemical treatment refers to the use of a chemical reaction or series of processes to improve the quality of water. Neutralization is a chemical procedure that is extensively utilised in many industrial wastewater treatment operations. The use of acid or base to return pH values to neutral is known as neutralization. In the biochemical degradation of wastewaters to stable end products, use microorganisms, primarily bacteria. Microorganisms are created, and some of the waste is transformed to carbon dioxide, water, and other end products (Wentzel *et al.,* 2003). Adsorption, physical-chemical treatment, anaerobic biological process, aerated lagoons, activated sludge process, biofilm-based reactor, membrane separation, coagulation/ flocculation, and electro-coagulation are examples of other processes that may or may not contain a combination of two treatment processes.

Some of the main pollutants of waste water and treatment methods are as follows:

COD

The amount of oxygen required to oxidise all soluble and insoluble organic molecules present in a volume of water is known as the Chemical Oxygen Demand (COD). The concentration of COD is commonly measured in milligrammes per litre of water (mg/L). The amount of oxygen necessary to decompose all oxidizable chemicals in a determined sample of effluent is referred to as COD in wastewater. A COD test can be used to determine the COD value in wastewater. In water, a high chemical oxygen demand suggests higher quantities of oxidizable organic matter and, as a result, less dissolved oxygen (DO). Organic contamination can cause critical DO depletion, which can destroy aquatic life forms. Knowing the chemical oxygen demand in wastewater treatment has a number of advantages, including assisting industrial and municipal clients in determining the optimum treatment method and the most efficient structure for their wastewater treatment facility. COD reduction in wastewater management can be accomplished in a variety of ways. The following are two of the most prevalent methods for removing COD from wastewater:

a) Separation of waste water (coagulation and flocculation)

Using coagulants and flocculants to remove organic debris from wastewater decreases the 'food' required for bacteria to grow, lowering the competition for dissolved oxygen with marine life. In coagulation, a non-toxic agglomerating substance, such as Ferric Chloride (FeCl) or alum, is added to the water to bind all of the suspended particles together into clumps that can be easily collected from effluent by filtration. Flocculation is a method of removing clumped particles from water by creating bigger particles, or flocs, using a chemical polymer (flocculating agent). The flocs are subsequently placed into a sedimentation tank for further treatment before being disposed of, as part of the wastewater treatment process.

b) Microbial action for COD removal

Incorporating bacteria or microbes that break down organic compounds in wastewater is another effective COD reduction method. In sewage treatment, microbes can be aerobic or anaerobic. In the absence of oxygen, anaerobic COD removal uses bacteria to convert organic molecules in wastewater to biomass. It is a very advantageous technology since the ethanol produced can be used as an alternative energy source for electricity, heating, and drying applications. Anaerobic COD removal is appropriate for wastewater with a COD concentration of more than 2000 mg/L. In the presence of air, aerobic COD

removal introduces microorganisms or bacteria that break down organic components in wastewater into carbon dioxide and water. Aerobic COD removal is best for wastewater with a COD concentration of less than 3000 mg/L.

Table 1: Overview of work done to remove COD as the pollutant in wastewater.

Sl. No.	Reference	Method	Removal efficiency
1	Satyawali & Balakrishnan, 2008	Aerobic Biological Process	86%
2	Gasim *et al.,* 2013	UASB reactor (Anaerobic process)	82%
3	Wang, Wang, Li, Yang, He, Yan, *et al.,* 2016	Up-flow anaerobic sludge bed reactor	70%
4	Zou, 2015	Up-flow anaerobic sludge blanket reactor and a two-stage biological aerated filter system	90.%
5	Nasirpour *et al.,* 2015	UASB and anaerobic packed-bed biofilm reactor	81%
6	Vendramel *et al.,* 2015	Anaerobic submerged fixed-bed reactor (ASFBR)	91%
7	Rahman & Al-Malack, 2012	Cross-flow membrane bioreactor	93%
8	Razavi & Miri, 2015	The hollow-fiber membrane bioreactor	82%
9	Asatekin & Mayes, 2009	Ultra-filtration membranes	44%
10	Farajnezhad *et al.,* 2012	Poly aluminium chloride and ferric chloride for coagualation treatment	58%
11	Wagner & Nicell, 2001	Subsequent coagulation	58%
12	Altaher *et al.,* 2011	Coagualation by alum	61%
13	Altaher *et al.,* 2011	Coagualation by ferric chloride	52%
14	El-Naas *et al.,* 2010	An activated carbon adsorption	60%
15	Sun *et al.,* 2008	A microwave-assisted catalytic wet air oxidation process	90%
16	Al-malack & Al-malack, 2015	Immersed membrane technique	92%
17	Palaniandy *et al.,* 2015	TiO_2/Fenton ($TiO_2/H_2O_2/Fe^{2+}$/sunlight) solar photo-catalyst in the Advanced oxidation process (AOP)	48%

Phenol

Due to the flow of polluted wastewater from industrial, agricultural, and residential activities into water bodies, phenolic compounds exist. These chemicals are known to be harmful to humans and animals, causing both immediate and long-term damage. Even at low quantities, they operate as carcinogens and destroy red blood cells and the liver. When these compounds interact with bacteria, inorganic, and other organic substances in water, substituted compounds or other moieties can form, which are potentially as dangerous as the original phenolic compounds. Because the characteristics of industrial wastewater fluctuate significantly from one industry to the next, industrial wastewater treatment processes are frequently different. Several methods are widely applied for the removal of phenol from wastewater. The solvent extraction method is widely used, allowing for the separation of phenol from wastewater for reuse. This process includes liquid or liquid-liquid extractions, which are often followed by carbon or biological adsorption to remove all phenol. Adsorption is also effective, which can be suitable from low to high phenol concentrations, depending upon economics and recyclability of secondary adsorbent material. The most common industrial adsorbent used for eliminating trace chemical pollutants in a system is activated carbon, though expensive. Other emerging membrane techniques are used in the removal of organic pollutants, including phenolic compounds, from water and wastewater. These methods are valued for low energy consumption, minimal operating costs, and scalability through membrane modules, making them a promising option for phenol removal.

Table 2: Overview of work done to remove Phenol as the pollutant in wastewater.

Sl. No.	Reference	Method	Removal efficiency
1	Al Hashemi *et al.,* 2015	Sequencing batch reactor system	98%
2	Vendramel *et al.,* 2015	Electro-coagulation	100%
3	Abdelwahab *et al.,* 2009	Cell with horizontally oriented aluminium cathode and horizontal aluminium screen anode at high current density	97%
4	Al-malack & Al-malack, 2015	Immersed membrane technique	53%

Oil

In a refinery's wastewater treatment, three types of oil are met. They are as follows:

1. Free oil or floating oil: Skimming the surface in the skim tank or gravity separation in the API separator are both used to extract free oil or floating oil.
2. Emulsified Oil is made up of oil droplets suspended in a stable suspension in wastewater. Chemicals are added to reduce the pH, then dissolved oxygen or nitrogen is added to remove the emulsified oils when they break free from the effluent.
3. Dissolved Oil is a molecular solution in water that can only be eliminated through biological treatment.

Table 3: Overview of work done to remove Oil as the pollutant in wastewater

Sl. No.	Reference	Method	Removal efficiency
1	Zhao *et al.,* 2006	The reactor immobilized with microorganisms	94%
2	Zou, 2015	Up-flow anaerobic sludge blanket reactor and a two-stage biological aerated filter system	86.5%
3	Wang, Wang, Li, Yang, He, & Yan, 2016	Up-flow anaerobic sludge bed (UASB) reactor	72%
4	Zeng *et al.,* 2007	Poly-zinc silicate and anion polyacrylamide for coagualation/flocculation treatment	99%
5	Moslehyani *et al.,* 2015	Polyvinylidene fluoride (PVDF) nanocomposite membranes with different fillers, MWCNTs with and without oxidisation	90%

Brief review of some of the work done in by different researchers the area of wastewater treatment:

Levent Altas *et al.* studied the removal of Sulfide from refinery effluent by physicochemical technique using a typical coagulant including iron, as well as interactions between iron and sulphide in the wastewater. Both Fe^{2+} and Fe^{3+}ions were used and it was

observed that Sulfide and COD removal efficiency of Fe^{3+} ions alone for sulphide added wastewaters with different pH values range from 62–95% and 45–75%, respectively. For sulphide removal, Fe^{2+}ion is more cost-effective than other precipitants but the Fe^{3+} ion is better for refinery wastewater with a pH of around 7. Thus. chemicals containing $Fe^{2+}$and Fe^{3+} should be used with caution, as Fe^{2+}can be rapidly oxidised by oxygen in the air, whilst Fe^{3+} can easily create hydroxide in water with a neutral or mildly alkaline pH(Altas, 2008).
Yu Wang *et al.* used an up-flow anaerobic sludge bed (UASB) reactor to treat heavy oil refinery wastewater with high levels of polar organics. At an organic loading rate (OLR) of 3.44 kg COD/m^3 d, average COD and total oil removal efficiencies reached 70% and 72%, respectively, when hydraulic conditions were gradually increased. The research showed that UASB might be used as a high-efficiency anaerobic treatment option for heavy oil refinery wastewater (Wang, Wang, Li, Yang, He, & Yan, 2016).

A. Moslehyani *et al.* designed and studied the performance of a hybrid system comprising of a photocatalytic reactor and a membrane permeation cell. The filtration cell was used to test five Polyvinylidene fluoride (PVDF) nanocomposite membranes with different fillers, MWCNTs with and without oxidisation by acid treatment, for the removal of oily organic contaminants in petroleum refinery effluent. In the photocatalytic reactor, more than 90% of the organic contaminants were destroyed (Moslehyani *et al.,* 2015).

Muhammad H. Al-Malack used an immersed membrane technique to remediate existing effluent from a petroleum refinery. The synthetic wastewater experiment was run in constant flux mode (15, 25, and 40 l/m^2 h) with oil levels of 20, 50, and 100 mg/l, enabling the transmembrane pressure (TMP) to rise with time. The real wastewater investigation, on the other hand, was carried out at permeate flux values of 15, 25, and 40 l/m^2 h. The investigation's findings revealed that wastewater oil content and permeate flux values had a significant impact on membrane performance. Based on the reported average, maximum, and minimum values, COD elimination efficiency was found to be 84, 83, and 92 %, respectively. Based on average and maximum readings, phenol elimination efficiency was found to be 42 and 53 %, respectively(Al-malack & Al-malack, 2015).

Yong Sun *et al.* developed a microwave (MW)-assisted catalytic wet air oxidation (CWAO) method at low temperature (15^0C) and low pressure (0.8MPa) to treat significantly contaminated petroleum effluent from the oil refining sector. The end results of the experiment showed that more than 90% of chemical oxygen demand (COD) was removed, and the biodegradability of the BOD_5/COD ratio increased from 0.04 to 0.47 in 30

minutes, indicating a significant increase in biodegradability for the solution, which is beneficial for further biotreatment of petroleum wastewater. This procedure can be run at lower pressures and temperatures. As a result, it will lessen the risk of operation within conventional WAO or CWAO due to high pressure and high temperature(Sun *et al.,* 2008).

Table 4: List of methods used for wastewater treatment

Sl. No.	Method Used	Pollutants Removed	Removal Efficiency	Reference
1	Precipitation using chemicals containing $Fe^{2+}$and Fe^{3+}	Sulphide and COD (chemical oxygen demand)	75% and 95%	Altas, 2008
2	Up-flow anaerobic sludge bed (UASB)	COD and Oil	70%and 72%	Wang, Wang, Li, Yang, He, & Yan, 2016
3	Polyvinylidene fluoride (PVDF) nanocomposite membranes with different fillers, MWCNTs with andwithout oxidisation	Oil	90%	Moslehyani *et al.,* 2015
4	Immersed membrane technique	COD and Phenol	92% and 53%	Al-malack & Al-malack, 2015
5	Microwave (MW)-assisted catalytic wet air oxidation (CWAO) method	COD	90%	Sun *et al.,* 2008
6	TiO_2/Fenton ($TiO_2/H_2O_2/Fe^{2+}$/sunlight) solar photo-catalyst in the Advanced oxidation process (AOP)	Total organic carbon (TOC) and Total organic matter (COD) removal	64% and 48%	Palaniandy *et al.,* 2015
7	Electrocoagulation	Phenol	94.5%	Abdelwahab *et al.,* 2009

Dheeaa *et al.* examined the efficacy of a TiO_2/Fenton ($TiO_2/H_2O_2/Fe^{2+}$/sunlight) solar photo-catalyst in the Advanced oxidation process (AOP) on the degradation of total organic carbon (TOC) and chemical oxygen demand (COD) from petroleum waste water in

the Sohar oil refinery in Oman. The solar photo-Fenton technique is effective for treating petroleum effluent in acidic circumstances (pH<7) and is cost-effective because it uses free energy. The projections match the experimental results, total organic carbon (TOC) and total organic matter (COD) removal rates of 64 and 48%, respectively, with 0.5 ppm residual iron(Palaniandy *et al.,* 2015).

O. Abdelwahab*et al.* employed a cell with a horizontally oriented aluminium cathode and a horizontal aluminium screen anode, to investigates the prospect of using electrocoagulation to extract phenol from oil refinery waste effluent. The removal of phenol was studied using a variety of variables, including pH, working time, current density, initial phenol concentration, and NaCl addition. During electrocoagulation, phenol was removed by a combination of sweep coagulation and adsorption. The petroleum refinery wastewater had 94.5% of its initial phenol concentration reduced after 2 hours of electrocoagulation(Abdelwahab *et al.,* 2009). Table 4 shows various methods used for the removal of specific pollutants from wastewater, particularly in the context of industrial applications such as the petroleum industry.

Conclusion:

Water conservation is the area with tremendous potential for petroleum refining industry where effective management of wastewater will go a long way in environmental protection and maximization of resources utilization. Full reuse of the petroleum refining wastewater can be possible by proper treatment and can substantially reduce the use of freshwater supply, thus avoiding the entry of pollutants into natural water bodies. High-quality treated water has been produced because of the introduction of sophisticated water management technologies and used for cooling tower, manufacturing process, and many other support services. Modern treatment methods effectively handle the removal of contaminants, including COD, sulfides, oil, and phenol, in order to meet the stringent environmental standards. These efforts improve not only water recycling but also sustainability in operations within the petroleum industry. Through the integration of innovative technologies and efficient practices in water treatment, the industry is able to reduce its impact on the environment while serving global water conservation efforts. Such refinements and applications represent an increase in the drive toward more sustainable industrial operations. Recovery and reuse of water saves valuable resources, and the method also serves more general goals for environmental protection. Such measures are essential in highlighting the importance of wastewater treatment for achieving a balance

between industrial development and the preservation of ecosystems, thereby paving the way for a more sustainable and responsible petroleum refining industry.

References:

1. Abdelwahab, O., Amin, N. K., & El-Ashtoukhy, E. S. Z. (2009). Electrochemical removal of phenol from oil refinery wastewater. *Journal of Hazardous Materials*, *163*(2–3), 711–716. https://doi.org/10.1016/j.jhazmat.2008.07.016
2. Al-malack, M. H., & Al-malack, M. H. (2015). *Performance of constant-flux immersed UF membrane treating petroleum refinery wastewater refinery wastewater*. *3994*(December), 0–11. https://doi.org/10.1080/19443994.2015.1024753
3. Al Hashemi, W., Maraqa, M. A., Rao, M. V., & Hossain, M. M. (2015). Characterization and removal of phenolic compounds from condensate-oil refinery wastewater. *Desalination and Water Treatment*, *54*(3), 660–671. https://doi.org/10.1080/19443994.2014.884472
4. Altaher, H., ElQada, E., & Omar, W. (2011). Pretreatment of Wastewater Streams from Petroleum/Petrochemical Industries Using Coagulation. *Advances in Chemical Engineering and Science*, *01*(04), 245–251. https://doi.org/10.4236/aces.2011.14035
5. Altas, L. (2008). *Sulfide removal in petroleum refinery wastewater by chemical precipitation*. *June*. https://doi.org/10.1016/j.jhazmat.2007.08.076
6. Asatekin, A., & Mayes, A. M. (2009). Oil industry wastewater treatment with fouling resistant membranes containing amphiphilic comb copolymers. *Environmental Science and Technology*, *43*(12), 4487–4492. https://doi.org/10.1021/es803677k
7. Chevrontexaco, K. A. (2005). *Water Resource Management in the Petroleum Industry*.
8. El-Naas, M. H., Al-Zuhair, S., & Alhaija, M. A. (2010). Reduction of COD in refinery wastewater through adsorption on date-pit activated carbon. *Journal of Hazardous Materials*, *173*(1–3), 750–757. https://doi.org/10.1016/j.jhazmat.2009.09.002
9. Farajnezhad, H., Gharbani, P., & Branch, A. (2012). Coagulation Treatment of Wastewater in Petroleum Industry using Poly Aluminium Chloride and Ferric. *Ijrras*, *13*(October), 306–310.
10. Gasim, H. A., Kutty, S. R. M., Isa, M. H., & Alemu, L. T. (2013). Optimization of anaerobic treatment of petroleum refinery wastewater using artificial neural networks. *Research Journal of Applied Sciences, Engineering and Technology*, *6*(11), 2077–2082. https://doi.org/10.19026/rjaset.6.3827
11. Hazardous Substance Research Center. (2003). Us Stance. *Environmental Impact of*

the Petroleum Industry.

12. Moslehyani, A., Ismail, A. F., Othman, M. H. D., & Matsuura, T. (2015). Design and performance study of hybrid photocatalytic reactor-PVDF / MWCNT nanocomposite membrane system for treatment of petroleum re fi nery wastewater. *DES*, *363*, 99–111. https://doi.org/10.1016/j.desal.2015.01.044
13. Nasirpour, N., Mousavi, S. M., & Shojaosadati, S. A. (2015). Biodegradation potential of hydrocarbons in petroleum refinery effluents using a continuous anaerobic-aerobic hybrid system. *Korean Journal of Chemical Engineering*, *32*(5), 874–881. https://doi.org/10.1007/s11814-014-0307-9
14. Palaniandy, P., Bin, H., Aziz, A., & Feroz, S. (2015). Journal of Environmental Chemical Engineering Treatment of petroleum wastewater using combination of solar photo-two catalyst TiO 2 and photo-Fenton process. *Biochemical Pharmacology*. https://doi.org/10.1016/j.jece.2015.04.012
15. Rahman, M. M., & Al-Malack, M. H. (2012). Biochemical kinetics of cross flow membrane bioreactor processes in the treatment of refinery wastewater. *International Journal of Environmental Research*, *6*(1), 285–296.
16. Raimi, O. M., Ezekwe, C. I., Bowale, A., & Samson, T. K. (2022). *Hydrogeochemical and Multivariate Statistical Techniques to Trace the Sources of Ground Water Contaminants and Affecting Factors of Groundwater Pollution in an Oil and Gas Producing Wetland in Rivers State , Nigeria*. *6*, 166–202. https://doi.org/10.4236/ojogas.2022.73010
17. Razavi, S. M. R., & Miri, T. (2015). A real petroleum refinery wastewater treatment using hollow fiber membrane bioreactor (HF-MBR). *Journal of Water Process Engineering*, *8*, 136–141. https://doi.org/10.1016/j.jwpe.2015.09.011
18. Requirements, W., & Selected, O. F. (1963). *Water Requirements of the Petroleum Refining Industry*.
19. Satyawali, Y., & Balakrishnan, M. (2008). Wastewater treatment in molasses-based alcohol distilleries for COD and color removal: A review. *Journal of Environmental Management*, *86*(3), 481–497. https://doi.org/10.1016/j.jenvman.2006.12.024
20. Sun, Y., Zhang, Y., & Quan, X. (2008). *Treatment of petroleum refinery wastewater by microwave-assisted catalytic wet air oxidation under low temperature and low pressure*. *62*, 565–570. https://doi.org/10.1016/j.seppur.2008.02.027
21. Vendramel, S., Bassin, J. P., Dezotti, M., & Sant'Anna, G. L. (2015). Treatment of petroleum refinery wastewater containing heavily polluting substances in an aerobic

submerged fixed-bed reactor. *Environmental Technology (United Kingdom)*, *36*(16), 2052–2059. https://doi.org/10.1080/09593330.2015.1019933

22. Wagner, M., & Nicell, J. A. (2001). Peroxidase-catalyzed removal of phenols from a petroleum refinery wastewater. *Water Science and Technology*, *43*(2), 253–260. https://doi.org/10.2166/wst.2001.0097
23. Wang, Y., Wang, Q., Li, M., Yang, Y., He, W., & Yan, G. (2016). An alternative anaerobic treatment process for treatment of heavy oil refinery wastewater containing polar organics An alternative anaerobic treatment process for treatment of heavy oil refinery wastewater containing polar organics. *Biochemical Engineering Journal*, *105*(January), 44–51. https://doi.org/10.1016/j.bej.2015.08.012
24. Wang, Y., Wang, Q., Li, M., Yang, Y., He, W., Yan, G., & Guo, S. (2016). An alternative anaerobic treatment process for treatment of heavy oil refinery wastewater containing polar organics. *Biochemical Engineering Journal*, *105*, 44–51. https://doi.org/10.1016/j.bej.2015.08.012
25. Wentzel, M. C., Ekama, G. A., & Loewenthal, R. E. (2003). *Fundamentals of biological behaviour and wastewater strength tests*.
26. Zeng, Y., Yang, C., Zhang, J., & Pu, W. (2007). Feasibility investigation of oily wastewater treatment by combination of zinc and PAM in coagulation/flocculation. *Journal of Hazardous Materials*, *147*(3), 991–996. https://doi.org/10.1016/j.jhazmat.2007.01.129
27. Zhao, X., Wang, Y., Ye, Z., Borthwick, A. G. L., & Ni, J. (2006). Oil field wastewater treatment in Biological Aerated Filter by immobilized microorganisms. *Process Biochemistry*, *41*(7), 1475–1483. https://doi.org/10.1016/j.procbio.2006.02.006
28. Zou, X. L. (2015). Treatment of heavy oil wastewater by UASB-BAFs using the combination of yeast and bacteria. *Environmental Technology (United Kingdom)*, *36*(18), 2381–2389. https://doi.org/10.1080/09593330.2015.1030346

ASSOCIATION BETWEEN QUADRICEPS MUSCLE STRENGTH AND GAIT PARAMETERS IN PATIENTS WITH KNEE OSTEOARTHRITIS

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Abstract:

Background: Quadriceps muscle impairment is an obvious finding when examining the patient with OA knee. Studies have reported knee extensor muscle weakness to be a risk factor for knee osteoarthritis. The clinical symptoms of the OA knee lead to changes in kinetics and kinematics of the gait. It has proven that the weakness in the quadriceps muscle results in alteration in gait compared to the individuals who does not have OA knee. Hence, our main study aimed to observe the relationship between quadriceps muscle strength and gait parameters in the patients with knee osteoarthritis. In this study we assessed the feasibility of the main study.

Method: After obtaining approval from the institutional ethical committee, all the subjects who were referred to Physiotherapy OPD were screened and assessed according to the inclusion criteria. Those subjects who were recruited for the study, their quadriceps muscle strength was measured using 10 RM. Following this, spatial parameters were measured using measure tape.

Result & Discussion: Total 10 subjects (60-76yrs) were recruited for the study. Out of 10 patients, 05 were males and 05 were females. There average BMI was 46.88 kg/m^2. All the patients were able to understand the command for 10 RM. Also, there were able to take instructions to stand on inkpad and walk on plain white paper.

Conclusion: Through this pilot study, the feasibility of the main study was assessed. The main study is feasible without modifying the study design.

Keywords: Osteoarthritis, Knee OA, Quadriceps, Repetitive Maximum, Gait.

Introduction:

The quadriceps muscle group, comprising the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius,(1–6) plays a critical role in maintaining the stability(7) and mobility of the lower limb. This group of muscles is essential for knee extension, a key movement in daily activities such as walking,(8–11) running(8,12), and climbing stairs(13–

16). The strength of the quadriceps, therefore, is a significant determinant of an individual's functional capacity(17,18) and overall mobility(19). Among the various aspects of human movement, gait is one of the most fundamental, reflecting the ability to move efficiently and safely in different environments.(10,20,21) The relationship between quadriceps muscle strength and gait parameters is an area of significant interest in both clinical and research settings, as it provides insights into the mechanisms of movement and potential interventions for improving mobility.(22–25)

Gait is a complex, coordinated movement involving the integration of multiple muscle groups, joints, and neurological processes.(26,27) It can be broadly divided into the stance phase, where the foot is in contact with the ground, and the swing phase, where the foot is lifted and moved forward.(11,28,29) The quadriceps muscles are particularly active during the stance phase,(8,30) where they contribute to knee stability and control during weight acceptance and mid-stance. Their role in controlling knee extension and absorbing impact forces during walking is crucial for maintaining a smooth and efficient gait cycle.

The strength of the quadriceps muscles is known to influence several key gait parameters, including walking speed, stride length, and cadence.(31) Walking speed, a commonly measured gait parameter, reflects the overall efficiency of the gait cycle and is influenced by the force-generating capacity of the lower limb muscles.(32) Individuals with stronger quadriceps muscles tend to walk faster, as they can generate greater propulsive forces during the push-off phase of gait. Stride length, or the distance covered between successive placements of the same foot, is also positively correlated with quadriceps strength. A longer stride length indicates a more powerful and efficient gait, which is often observed in individuals with greater muscle strength.

Moreover, cadence, defined as the number of steps taken per minute, is another gait parameter influenced by quadriceps strength. A higher cadence can indicate a more dynamic and responsive gait, often associated with better muscle strength and coordination. Conversely, individuals with weakened quadriceps may exhibit a reduced walking speed, shorter stride length, and lower cadence, reflecting the compromised function of the muscle group and its impact on overall mobility.

The association between quadriceps muscle strength and gait parameters is particularly relevant in various populations, including the elderly, individuals with osteoarthritis, and those recovering from lower limb injuries or surgeries. In older adults, age-related muscle loss, known as sarcopenia, often leads to a decline in quadriceps

strength, which in turn affects gait and increases the risk of falls.(33) In individuals with knee osteoarthritis, quadriceps weakness is a common finding and is associated with altered gait patterns, such as reduced walking speed and shorter stride length, which can contribute to pain and disability. Rehabilitation programs aimed at strengthening the quadriceps have been shown to improve gait parameters in these populations, highlighting the importance of maintaining muscle strength for functional mobility.

In addition to strength, other factors such as muscle endurance, coordination, and neuromuscular control also play a role in determining gait parameters. However, the primary focus of this chapter is on the relationship between quadriceps muscle strength and specific gait parameters, including walking speed, stride length, and cadence. By understanding this association, clinicians and researchers can better identify individuals at risk of mobility impairments and develop targeted interventions to improve gait and overall quality of life.

Hence, our main study aimed to observe the relationship between quadriceps muscle strength and gait parameters in the patients with knee osteoarthritis. In this study we assessed the feasibility of the main study.

Method: Total 10 subjects who were diagnosed as having unilateral osteoarthritis of knee were recruited from the physiotherapy OPD for the study. The participants with age ≥ 60years were recruited. Any patients with secondary OA knee, replacement surgery at the knee joint, systemic arthritis condition or any other pathology that would impair ambulation or lower extremity functions were excluded.

Procedure: The subject was taken to the procedure room. They were assessed based on their complaints. Their knee ROM was assessed using goniometer. Following this, the subject was asked to sit in a high sitting position on a plinth to assess their quadriceps muscle strength using sand bag. A sand bag was tied on their ankle joint of the unaffected limb. The principle investigator demonstrated the knee extension movement. The subject was asked to perform knee extension for 10 repetitions. It was also informed that if there is a mild discomfort or fatigue or joint pain during the test then the subject has to stop the movement and rest. The principal investigator then gave the command to perform 10 RM and as per the quadriceps strength, the sand bags were changed after the 10 RM. The weight which was smoothly lifted was noted by the principle investigator. The same procedure was repeated for the affected limb. After completing the quadriceps muscle strength assessment of the subject, the principle investigator measured the gait

parameters. To measure Step length and Stride length, the patient was asked to remove their footwear & socks. The patient was explained about the procedure and was instructed to stand on an inkpad. Then the patient was asked to walk forward at his pace on a plain white paper. The foot prints of the patient were imprinted on the paper. Step length was measured as the distance between two consecutive heel-strikes of the contralateral limbs and stride length will be measured as the distance between two consecutive heel-strikes of the ipsilateral limb using measure tape.

Statistical analysis: Descriptive analysis was carried out for age, gender, knee involvement, muscle strength, and gait parameters.

Results: Total 10 patients were recruited for the study. The mean age of the patients was 68.4 yrs. Of these 10 patients, 05 were females and 05 were males (Figure 1). The mean age of females was 67.2 years and that of males was 69.6 years. All of them suffered unilateral knee OA. 03 subjects showed right knee involvement and 07 subjects showed left knee involvement (Figure 2). 01 subject had grade 1 knee OA, 03 subjects had grade 02 OA knee, 02 subjects had grade 03 OA knee, and 04 subjects had grade 04 OA knee (Figure 3).

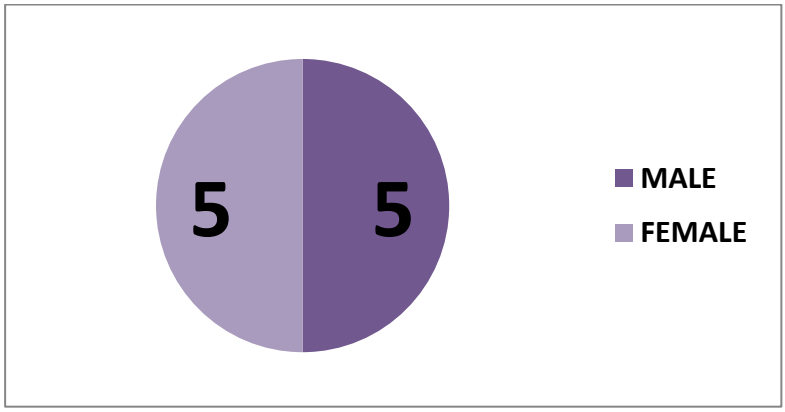

Fig. 1: Pie chart showing number of males and females

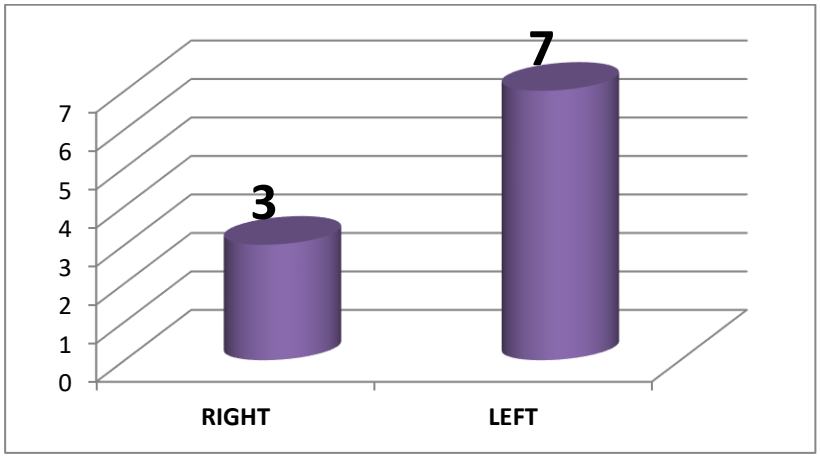

Fig. 2: The bar graph shows the side of involvement of knee joint in OA patients

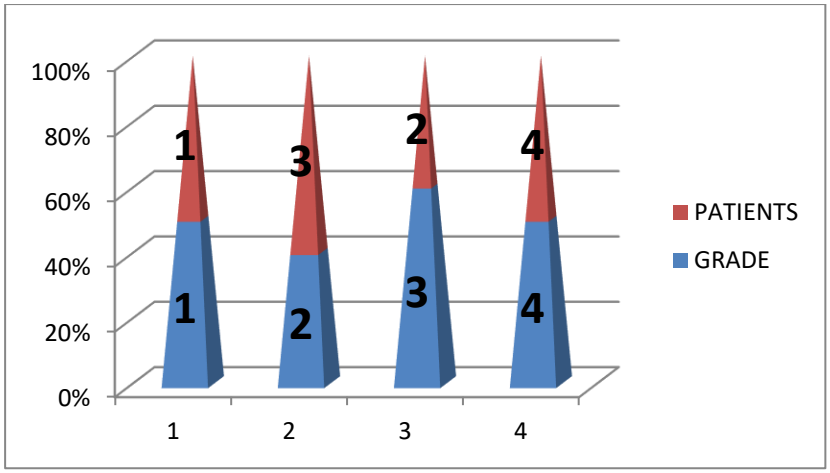

Fig. 3: The bar graph shows the number of patients having grade 1, 2, 3 and grade 4 Knee OA

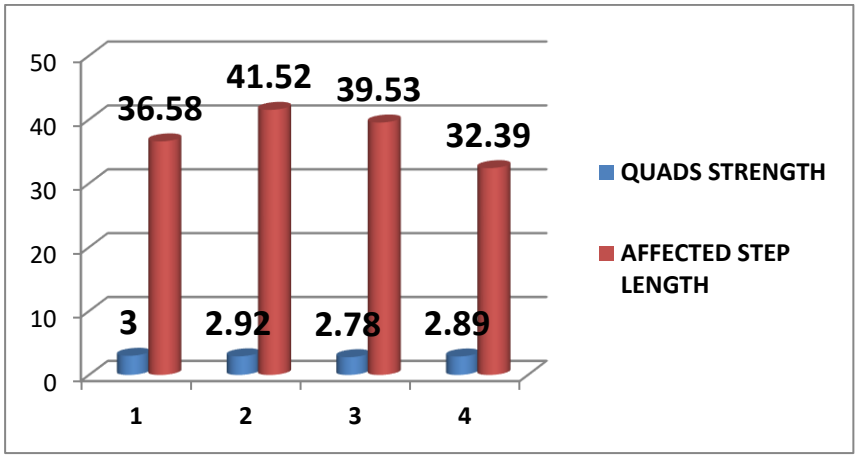

Fig. 4: The bar graph shows the comparison of the Quadriceps strength with Step Length as per the Knee Osteoarthritis K-L grades

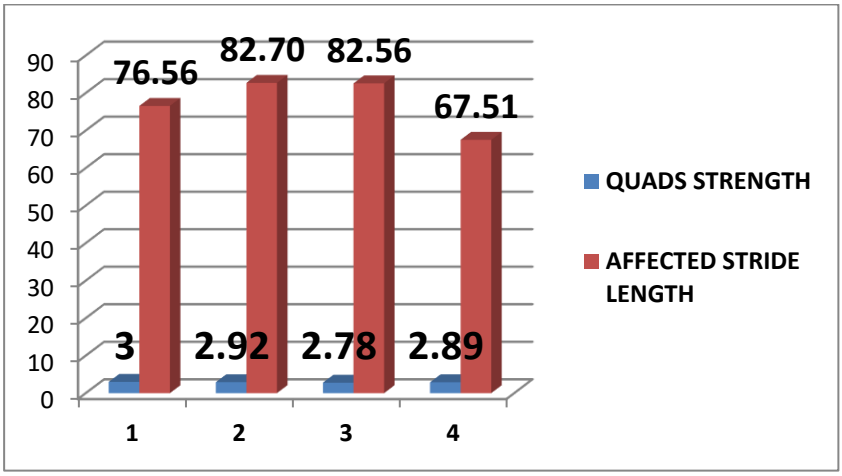

Fig. 5: The bar graph shows the comparison of the Quadriceps strength with Stride Length as per the Knee Osteoarthritis K-L grades

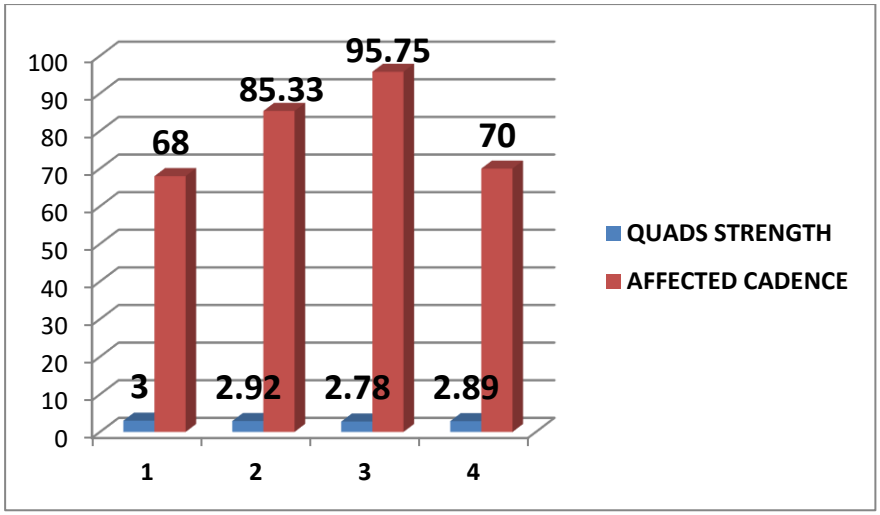

Fig. 6: The bar graph shows the comparison of the Quadriceps strength with Cadence as per the Knee Osteoarthritis K-L grades

Discussion:

The objective of the study was to assess the feasibility of the study. In India commonly used position in ADLs and daily living are squatting and cross-legged sitting(34). As per the result of the pilot study, we received patients of unilateral OA knee with grade 1, 2, 3, and 4. No issues of willingness to participate in the study were encountered. Subjects showed enthusiasm to get their quadriceps muscle strength assessed using sand bags. No discomfort was reported on tying the sand bags at the ankle joint. Similarly, patient did not hesitate to stand on the ink pad and to walk on the plain white paper. No patients had any side-effect of the ink which was applied on their sole.

It took 15-20 minutes to completely assess the subject and hence the subjects were not hesitated to participate in the study.

Conclusion:

Through this pilot study, feasibility of the main study was assessed. The main study is feasible without modifying the study design.

References:

1. Olewnik Ł, Tubbs RS, Ruzik K, Podgórski M, Aragonés P, Waśniewska A, et al. Quadriceps or multiceps femoris?—Cadaveric study. Clinical Anatomy. 2021 Jan;34(1):71–81.
2. Grob K, Ackland T, Kuster MS, Manestar M, Filgueira L. A newly discovered muscle: The tensor of the vastus intermedius. Clinical Anatomy. 2016 Mar;29(2):256–63.
3. Chavan S, Wabale R. Reviewing morphology of Quadriceps femoris muscle. J Morphol Sci. 2016 Apr;33(02):112–7.

4. Yoshida S, Ichimura K, Sakai T. Structural diversity of the vastus intermedius origin revealed by analysis of isolated muscle specimens. Clinical Anatomy. 2017 Jan;30(1):98–105.
5. Olewnik Ł, Ruzik K, Szewczyk B, Podgórski M, Aragonés P, Karauda P, et al. The relationship between additional heads of the quadriceps femoris, the vasti muscles, and the patellar ligament. Du J, editor. BioMed Research International. 2022 Feb 16;2022:1–11.
6. Grob K, Manestar M, Filgueira L, Kuster MS, Gilbey H, Ackland T. The interaction between the vastus medialis and vastus intermedius and its influence on the extensor apparatus of the knee joint. Knee Surg Sports Traumatol Arthrosc. 2018 Mar;26(3):727–38.
7. Abulhasan J, Grey M. Anatomy and Physiology of Knee Stability. JFMK. 2017 Sep 24;2(4):34.
8. Halonen KS, Mononen ME, Jurvelin JS, Töyräs J, Kłodowski A, Kulmala JP, et al. Importance of Patella, Quadriceps Forces, and Depthwise Cartilage Structure on Knee Joint Motion and Cartilage Response During Gait. Journal of Biomechanical Engineering. 2016 Jul 1;138(7):071002.
9. Donno L, Sansone V, Galluzzo A, Frigo CA. Walking in the Absence of Anterior Cruciate Ligament: The Role of the Quadriceps and Hamstrings. Applied Sciences. 2022 Aug 29;12(17):8667.
10. Spinoso DH, Bellei NC, Marques NR, Navega MT. Quadriceps muscle weakness influences the gait pattern in women with knee osteoarthritis. Adv Rheumatol. 2018 Dec;58(1):26.
11. Tanimoto K, Takahashi M, Tokuda K, Sawada T, Anan M, Shinkoda K. Lower limb kinematics during the swing phase in patients with knee osteoarthritis measured using an inertial sensor. Gait & Posture. 2017 Sep;57:236–40.
12. Verheul J, Clansey AC, Lake MJ. Adjustments with running speed reveal neuromuscular adaptations during landing associated with high mileage running training. Journal of Applied Physiology. 2017 Mar 1;122(3):653–65.
13. Casaña J, Calatayud J, Silvestre A, Sánchez-Frutos J, Andersen LL, Jakobsen MD, et al. Knee Extensor Muscle Strength Is More Important Than Postural Balance for Stair-Climbing Ability in Elderly Patients with Severe Knee Osteoarthritis. IJERPH. 2021 Mar 31;18(7):3637.

14. Riahi H, Activity of Quadriceps muscle among people with knee osteoarthritis during stair ascending and descending with different heights..pdf.
15. Briani RV, De Oliveira Silva D, Flóride CS, Aragão FA, De Albuquerque CE, Magalhães FH, et al. Quadriceps neuromuscular function in women with patellofemoral pain: Influences of the type of the task and the level of pain. Alway SE, editor. PLoS ONE. 2018 Oct 10;13(10):e0205553.
16. Suzuki Y, Iijima H, Shimoura K, Tsuboyama T, Aoyama T. Patients with early-stage knee osteoarthritis and knee pain have decreased hip abductor muscle strength while descending stairs. Clin Rheumatol. 2019 Aug;38(8):2249–54.
17. Chang TT, Zhu YC, Li Z, Li F, Li YP, Guo JY, et al. Modulation in the Stiffness of Specific Muscles of the Quadriceps in Patients With Knee Osteoarthritis and Their Relationship With Functional Ability. Front Bioeng Biotechnol. 2022 Feb 10;9:781672.
18. Carvalho C, Serrão FV, Mancini L, Serrão PRMDS. Impaired muscle capacity of the hip and knee in individuals with isolated patellofemoral osteoarthritis: a cross-sectional study. Therapeutic Advances in Chronic Disease. 2021 Jan;12:204062232110287.
19. Chopp-Hurley JN, Wiebenga EG, Bulbrook BD, Keir PJ, Maly MR. Evaluating the relationship between quadriceps muscle quality captured using ultrasound with clinical severity in women with knee osteoarthritis. Clinical Biomechanics. 2020 Dec;80:105165.
20. Prakash C, Kumar R, Mittal N. Recent developments in human gait research: parameters, approaches, applications, machine learning techniques, datasets and challenges. Artif Intell Rev. 2018 Jan;49(1):1–40.
21. Cruz-Jimenez M. Normal Changes in Gait and Mobility Problems in the Elderly. Physical Medicine and Rehabilitation Clinics of North America. 2017 Nov;28(4):713–25.
22. Christensen JC, Mizner RL, Foreman KB, Marcus RL, Pelt CE, LaStayo PC. Quadriceps weakness preferentially predicts detrimental gait compensations among common impairments after total knee arthroplasty. Journal Orthopaedic Research. 2018 Sep;36(9):2355–63.
23. Christensen JC, Capin JJ, Hinrichs LA, Aljehani M, Stevens-Lapsley JE, Zeni JA. Gait mechanics are influenced by quadriceps strength, age, and sex after total knee arthroplasty. Journal Orthopaedic Research. 2021 Jul;39(7):1523–32.

24. Tani K, Kola I, Shpata V, Dhamaj F. Evaluation of Gait Speed after Applying Kinesio Tape on Quadriceps Femoris Muscle in Patients with Knee Osteoarthritis. Open Access Maced J Med Sci. 2018 Aug 15;6(8):1394–8.
25. Rashid SA, Moiz JA, Sharma S, Raza S, Rashid SM, Hussain ME. Comparisons of Neuromuscular Training Versus Quadriceps Training on Gait and WOMAC Index in Patients With Knee Osteoarthritis and Varus Malalignment. Journal of Chiropractic Medicine. 2019 Mar;18(1):1–8.
26. Wilson J, Allcock L, Mc Ardle R, Taylor JP, Rochester L. The neural correlates of discrete gait characteristics in ageing: A structured review. Neuroscience & Biobehavioral Reviews. 2019 May;100:344–69.
27. Taborri J, Palermo E, Rossi S, Cappa P. Gait Partitioning Methods: A Systematic Review. Sensors. 2016 Jan 6;16(1):66.
28. Fukaya T, Mutsuzaki H, Nakano W, Mori K. Smoothness of the knee joint movement during the stance phase in patients with severe knee osteoarthritis. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology. 2018 Oct;14:1–5.
29. Kour N, Gupta S, Arora S. A Survey of Knee Osteoarthritis Assessment Based on Gait. Arch Computat Methods Eng. 2021 Mar;28(2):345–85.
30. Ogaya S, Kubota R, Chujo Y, Hirooka E, Kwang-ho K, Hase K. Muscle contributions to knee extension in the early stance phase in patients with knee osteoarthritis. Gait & Posture. 2017 Oct;58:88–93.
31. ElGendy MH, Zalabia MM, Moharram AN, Abdelhay MI. Efficacy of rectus femoris stretching on pain, range of motion and spatiotemporal gait parameters in patients with knee osteoarthritis: a randomised controlled trial. BMJ Open Sport Exerc Med. 2022 Dec;8(4):e001459.
32. Astephen Wilson JL, Kobsar D. Osteoarthritis year in review 2020: mechanics. Osteoarthritis and Cartilage. 2021 Feb;29(2):161–9.
33. Mitchell WK, Williams J, Atherton P, Larvin M, Lund J, Narici M. Sarcopenia, Dynapenia, and the Impact of Advancing Age on Human Skeletal Muscle Size and Strength; a Quantitative Review. Front Physio [Internet]. 2012 [cited 2024 Sep 3];3. http://journal.frontiersin.org/article/10.3389/fphys.2012.00260/abstract
34. Patel N, Khatri LR, Parmar L. Assessment of Functional End Ranges of Lower Limb Joints in Positions Commonly Used for ADLs in India. JPRI. 2021 Jul 3;64–71.

A COMPREHENSIVE GUIDE TO MARFAN SYNDROME

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Abstract:

Mutations in the FBN1 gene, which codes for fibrillin-1, a glycoprotein necessary for the structural integrity of elastic fibbers, result in Marfan syndrome, a heritable connective tissue condition. It is distinguished by a wide range of clinical symptoms that mostly impact the skeletal, ocular, and cardiovascular systems. Cardinal characteristics include scoliosis, pectus deformities, arachnodactyly, aortic root dilatation, tall stature, and lens displacement (ectopia lentis). The disorder has varied expressivity, partial penetrance, and an autosomal dominant inheritance pattern. Early detection and risk assessment have been enhanced by developments in molecular diagnostics and imaging. The goal of management is to reduce the risk of aortic problems by using timely surgical procedures and pharmaceutical treatments like beta-blockers or angiotensin receptor blockers. The genetic foundation, pathophysiology, clinical presentation, diagnostic standards, and interdisciplinary approaches to Marfan syndrome treatment are all covered in this chapter.

Keywords: Aortic Root Dilatation, Elastic Fibbers, Autosomal Dominant, Connective Tissue

Introduction:

French paediatrician Antoine Marfan initially identified Marfan syndrome (MFS), a systemic connective tissue condition, in 1896 after observing a patient with unusually lengthy fingers and limbs. It is an autosomal dominant disorder brought on by pathogenic variations in the FBN1 gene, which is found on chromosome 15 and codes for fibrillin-1, an essential microfibril component.[1] In addition to giving tissues structural support, these microfibrils control the bioavailability of transforming growth factor-beta (TGF-β), a signalling molecule linked to the disease's pathophysiology. Clinically speaking, Marfan syndrome is a multisystem condition that primarily affects the skeletal, ophthalmic, and cardiovascular systems. Progressive aortic root dilatation is the most dangerous consequence, since it puts those who have it at risk for aortic dissection and rupture. Ocular symptoms typically include myopia and ectopia lentis (lens displacement), whereas skeletal characteristics include tall stature, scoliosis, pectus deformities, and

arachnodactyly. Even among people who have the same genetic mutation, the syndrome's phenotypic expression differs greatly. Targeted diagnostic and treatment approaches have been made possible by developments in our knowledge of the molecular pathways underlying Marfan syndrome.[2] Improving results and quality of life requires early detection and interdisciplinary intervention. The goal of this chapter is to present a thorough analysis of Marfan syndrome, covering its molecular and genetic foundation, clinical manifestations, diagnostic standards, and current management and therapy strategies.

Epidemiology

Globally, the estimated prevalence of Marfan syndrome (MFS), a very uncommon genetic condition, ranges from 1 in 5,000 to 1 in 10,000. It affects men and women equally frequently and is equally prevalent in all racial and ethnic groupings. About 75% of cases are familial in nature, and the disease is inherited in an autosomal dominant way.[3] De novo mutations in the FBN1 gene are responsible for the remaining 25% of instances. Despite the strong penetrance of the genetic mutation causing Marfan syndrome, environmental factors, genetic modifiers, and epigenetic mechanisms can all have a substantial impact on how the condition manifests clinically.[4] Advances in genetic testing and increased knowledge have helped make diagnosis sooner and more accurate, which may eventually affect epidemiological data. Improvements in healthcare, especially in the early detection and treatment of aortic problems, have had a substantial impact on the condition's natural history.[5] While untreated Marfan syndrome historically resulted in a significantly lower life expectancy due to aortic dissection or rupture, early intervention has improved survival rates, with people today frequently living well into adulthood.[6-8]

Pathophysiology of Marfan Syndrome

Mutations in the FBN1 gene, which codes for fibrillin-1, a glycoprotein essential to the structural and functional integrity of extracellular microfibrils, result in Marfan syndrome (MFS), a multisystem connective tissue condition. These microfibrils are a crucial component of elastic fibers, which give connective tissues in the skeletal, cardiovascular, and ocular systems their strength and elasticity. Both structural abnormalities in connective tissues and dysregulated signalling pathways, specifically involving transforming growth factor-beta (TGF-β), are responsible for the pathophysiology of Marfan syndrome.[9]

- Molecular Mechanisms and Genetic Basis

Most cases of Marfan syndrome are brought on by heterozygous mutations in the chromosome 15q21.1 gene FBN1. Both decreased fibrillin-1 production and the creation of structurally aberrant fibrillin-1 are caused by these mutations. Defective fibrillin-1 weakens connective tissues all across the body by interfering with microfibril assembly. Additionally, TGF-β, a cytokine that controls tissue growth and repair, is often bound and sequestered by fibrillin-1. TGF-β is overactivated when fibrillin-1 is absent or malfunctioning, resulting in aberrant cellular signalling that promotes tissue remodelling, inflammation, and disintegration.[10-11]

- Functional and Structural Repercussions

1. Manifestations of Cardiovascular: Disease aorta root dilatation, which arises from the aorta wall's loss of elastic fiber integrity, is the most dangerous aspect of Marfan syndrome. Elastic fiber fragmentation, elevated matrix metalloproteinase (MMP) activity, and smooth muscle cell death are the hallmarks of this process. The aorta wall is weakened by these alterations, making it more vulnerable to aortic dissection, aneurysm development, and progressive dilatation.[12]

   - Due to extended and redundant valve leaflets brought on by aberrant connective tissue, mitral valve prolapse and regurgitation are also frequent.[13]

2. Manifestations at the Skeletal: Level Arachnodactyly (long, slender fingers), disproportionate height, and long limbs are all results of abnormal bone growth caused by dysregulated TGF-β signalling in the growth plates and periosteum. Ligamentous laxity raises the risk of joint dislocations and causes hypermobile joints. Common skeletal abnormalities that can seriously affect pulmonary function include scoliosis, pectus excavatum (sunken chest), and pectus carinatum (protruding chest).

3. Manifestations of the Eyes: Ectopia lentis, or lens dislocation, is a defining characteristic of Marfan syndrome caused by weakening of the ciliary zonules that suspend the lens inside the eye. Myopia, early-onset cataracts, and a higher risk of retinal detachment as a result of the ocular connective tissues' structural instability are other ocular problems.[14]

4. Skin, Pulmonary, and Additional Systems: Pneumothorax may occur spontaneously as a result of structural weakness in the alveolar walls of the lungs. Striae distensae, or stretch marks, are a type of skin involvement that happens without noticeable

weight changes. Back discomfort, neurological symptoms, or pregnancy issues can develop from Dural ectasia, a weakening of the dura mater covering the spinal cord.

- Systemic Consequences and Advancement: Because fibrillin-1 is widely distributed and its lack has systemic effects, Marfan syndrome is multisystemic. A major factor in the development of the disease is dysregulated TGF-β signalling, which intensifies inflammatory reactions and eventually leads to tissue remodelling and fibrosis.
- Therapeutic Consequences: Targeted treatments that lower TGF-β signalling and reduce the progression of the disease have been made possible by better understanding of the molecular mechanisms underlying Marfan syndrome. Angiotensin receptor blockers (ARBs), such losartan, which decrease TGF-β signalling, and beta-blockers, which lessen hemodynamic stress on the aortic wall, have demonstrated promise in reducing cardiovascular problems. Although early medical care has greatly increased life expectancy and quality of life for those with Marfan syndrome, surgical operations are still essential for controlling advanced aortic disease. This complex interaction between structural, molecular, and genetic elements highlights the intricacy of Marfan syndrome and the value of a multidisciplinary approach to its treatment.
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Clinical Presentation

There is significant variation in the severity and presentation of Marfan syndrome (MFS), a systemic condition that affects several organ systems. Although pulmonary, integumentary, and neurological disorders may also be present, the cardiovascular, skeletal, and ocular systems make up the majority of the clinical characteristics.[19] Many

of the characteristics that define Marfan syndrome develop over time; some start to show in childhood, while others grow or get worse as people age.

1. Cardiovascular System: The most severe feature of Marfan syndrome is cardiovascular involvement, which can be fatal if left untreated.
    - Aortic Root Dilatation: A characteristic that increases the chance of aortic dissection or rupture, especially in the ascending aorta, and causes aneurysm formation. Elongated and redundant valve leaflets are a common sign of mitral valve prolapse, which can lead to mitral regurgitation.
    - Other Valvular Abnormalities: Insufficiency may result from involvement of the tricuspid and aortic valves.
    - Arrhythmias: Due to structural problems, patients may experience irregular heart rhythms.
2. System Skeletal: People with Marfan syndrome frequently have the most noticeable skeletal signs, which also add to their distinctive physical characteristics. A thin, elongated body habitus is the outcome of disproportionate lengthy bone development in people with tall stature and long limbs. Long, thin fingers and toes are indicative of arachnodactyly, which is frequently indicated by the positive "thumb sign" (Steinberg sign) or "wrist sign." Pectus excavatum (sunken chest) or pectus carinatum (protruding chest) are examples of chest deformities. The progressive curvature of the spine, known as kyphosis and scoliosis, can affect respiratory function and posture in extreme cases.
    - Joint Hypermobility: Increased joint range of motion brought on by ligamentous laxity, which can cause frequent dislocations and joint discomfort.[20]
3. Ocular System: One of the main characteristics of Marfan syndrome that frequently helps with diagnosis is ocular involvement.
    - Ectopia Lentis: Weakened ciliary zonules cause the lens to dislocate, usually superiorly and temporally. Between 50 and 80 percent of patients have this.
    - Myopia: Near-sightedness of high grade is prevalent.
    - Retinal Detachment: A higher risk because to the retina's structural instability. Early-Onset Glaucoma and Cataracts: These conditions may manifest earlier than in the general population.

4. Pulmonary System
    - Spontaneous Pneumothorax: This condition results in the collapse of the lungs due to the rupture of subpleural blebs or bullae. The mechanics of the chest wall are hampered by restrictive lung disease, which is a result of severe scoliosis or pectus abnormalities. Anomalies of the craniofacial region may be the cause of obstructive sleep apnoea.
5. Integumentary System
    - Stretch Marks (Striae Distensae): These are unrelated to notable weight changes and are frequently found on the shoulders, lower back, or hips. Weakened connective tissues increase the chance of inguinal, umbilical, or other hernias.
6. Neurological System
    - Dural Ectasia: Proliferation of the Dural sac around the spinal cord, usually in the lumbosacral area, which can result in neurological symptoms, headaches, or back discomfort. Chiari Malformation: Infrequently linked to MFS, this condition can lead to neurological issues.

- Features That Depend on Age: In youngsters, the first indications could be characteristics like lens dislocation, joint hypermobility, and disproportionate growth. Aortic dilatation and mitral valve disease are two progressive cardiovascular symptoms that become more noticeable and potentially fatal in adults.
- Implications for Diagnosis: The updated Ghent criteria, which highlight the significance of key characteristics including aortic root dilatation and ectopia lentis, as well as the existence of a verified FBN1 mutation, are frequently used to assess the clinical presentation of Marfan syndrome. It is essential to identify these clinical indicators early in order to avoid problems and start the right treatment. Clinicians can treat the entire range of Marfan syndrome's clinical manifestations by using a multidisciplinary approach once they have a thorough understanding of the disorder's complex and systemic nature.

Treatment Approaches [21]

A comprehensive approach is necessary for the treatment of Marfan syndrome (MFS), with the goals of lowering the risk of potentially fatal consequences, controlling symptoms in several organ systems, and enhancing the patient's quality of life. Treatment

aims to address skeletal and visual signs, limit the progression of cardiovascular disease, and monitor for consequences through routine follow-up.

1. Management of Cardiovascular Disease: The main cause of morbidity and death in Marfan syndrome is cardiovascular problems, specifically aortic root dilatation and dissection. The goal of management is to avoid aortic problems and lessen hemodynamic stress. Pharmaceutical Treatment: -
    - Beta-Blockers: Lower the systolic blood pressure and heart rate to lessen the mechanical strain on the aortic wall. Propranolol and atenolol are frequently used agents.
    - ARBs (Angiotensin Receptor Blockers): These drugs, like valsartan or losartan, have been demonstrated to reduce the pace of aortic dilatation by blocking TGF-β signaling. ARBs are frequently used in place of or in addition to beta-blockers. Patients who are unable to tolerate beta-blockers may be candidates for calcium channel blockers.
    - Prophylactic aortic root replacement: It is advised when the aortic root diameter surpasses 4.5 to 5.0 cm, or sooner if there is fast dilatation. Techniques include composite graft replacement and valve-sparing aortic root replacement (David procedure).
    - Aortic Dissection Management: In order to repair the damaged segment, aortic dissection requires emergency surgery.
    - Regular Monitoring: Echocardiography on a regular basis to track the size of the aorta and its dilatation. For a more thorough evaluation, particularly in cases of distal aortic involvement, MRI or CT imaging may be utilized.
2. Management of Skeletal Structure: In Marfan syndrome, skeletal abnormalities can affect posture, function, and general quality of life.

    Treatments for Orthopaedic Conditions: -
    - Scoliosis Management: While severe deformities may necessitate surgical correction, mild cases can be controlled with bracing or observation. In order to improve cardiopulmonary function, severe cases of pectus excavatum or carinatum may require surgical treatment.
    - Physical Therapy: Assists in strengthening muscles, reducing joint pain from hypermobility, and improving posture.

- Activity Modification: High-impact or contact sports are discouraged for patients as they may raise the risk of joint dislocation or aortic rupture.

3. Ocular Management: To avoid vision loss, ocular disorders must be identified and treated as soon as possible.
    - Ectopia Lentis Lens Dislocation: The first line of treatment is usually contact lenses or corrective lenses. In extreme situations, surgical lens insertion and removal may be required.
    - Refractive Errors: Glasses or contact lenses are used to treat myopia and astigmatism.
    - Retinal Detachment: This condition necessitates immediate surgical surgery.
    - Glaucoma and Cataracts: Early detection and treatment are essential for these disorders.
4. Management of Pulmonary Functions: Although they are less frequent, pulmonary problems may call for particular treatments. The management of spontaneous pneumothorax involves the insertion of a chest tube and, in circumstances that occur frequently, pleurodesis or surgical repair. Treatment options for obstructive sleep apnoea include weight control or continuous positive airway pressure (CPAP) therapy, depending on the situation.
5. Neurological Management:
    - Dural Ectasia: While severe cases may necessitate neurosurgical surgery, symptomatic cases are conservatively handled with pain management.
    - Chiari Malformation: If it exists, major symptoms may need surgical decompression.
6. Psychological and Genetic Counselling:
    - Psychological Support: Patients and their families may find that counselling or support groups help them deal with the difficulties of having Marfan syndrome. For impacted individuals and their families to comprehend the inheritance pattern and risk of transfer to kids, genetic counselling is advised. Families that are at risk may be provided prenatal genetic testing.
7. Management of Pregnancy: Because pregnancy increases cardiovascular strain, especially on the aorta, there are serious hazards. It is recommended that women with Marfan syndrome receive prenatal counselling and a thorough cardiovascular assessment. Throughout pregnancy, close observation is crucial, including regular

echocardiograms. While caesarean birth is recommended for patients with considerable aortic dilatation, vaginal delivery may be feasible for patients with stable aortic dimensions.

8. Lifestyle and Long-Term Monitoring: It is crucial to have regular follow-ups with a multidisciplinary team that includes geneticists, cardiologists, orthopaedic surgeons, and ophthalmologists. Reducing overall complications requires lifestyle changes, such as quitting smoking and keeping a healthy weight.

- New Treatments Novel therapeutics, including as TGF-β inhibitors and gene-editing technologies, have been made possible by advances in our understanding of the molecular pathways underlying Marfan syndrome. These treatments may eventually offer more specialized and efficient choices. It is essential to identify these clinical indicators early in order to avoid problems and start the right treatment. Clinicians can treat the entire range of Marfan syndrome's clinical manifestations by using a multidisciplinary approach once they have a thorough understanding of the disorder's complex and systemic nature.[22]

Conclusion:

A complicated, multisystemic connective tissue disorder with considerable clinical diversity is Marfan syndrome (MFS). The FBN1 gene mutations that cause structural abnormalities in connective tissues and dysregulated TGF-β signalling are at the heart of its pathophysiology. The condition mostly affects the skeletal, cardiovascular, and ophthalmic systems; the most serious issues are life-threatening consequences including aortic dissection and rupture. Understanding the molecular underpinnings of Marfan syndrome has revolutionized its prognosis, treatment, and diagnosis. The updated Ghent criteria have improved the accuracy of diagnosis, allowing for earlier detection and treatment. Effective management continues to be based on multidisciplinary care, which includes specialized approaches to ophthalmic and pulmonary problems, surgical procedures to treat aortic and skeletal consequences, and pharmaceutical treatments including beta-blockers and ARBs. Lifelong monitoring and genetic counseling are crucial for maximizing results and enhancing quality of life. The prognosis for people with Marfan syndrome has greatly improved with the introduction of targeted treatments and continued research into new treatment approaches. Reducing morbidity and mortality requires early detection, consistent monitoring, and an all-encompassing, patient-centered treatment strategy. The knowledge gathered from researching Marfan syndrome also continues to influence more

general theories of connective tissue biology and other conditions, advancing medical research.

References:

1. Hollister, D. W., Godfrey, M., Sakai, L. Y., & Pyeritz, R. E. (1990). Immunohistologic abnormalities of the microfibrillar-fiber system in the Marfan syndrome. *New England Journal of Medicine, 323*(3), 152–159.
2. Sakai, L. Y., Keene, D. R., & Engvall, E. (1986). Fibrillin, a new 350-kD glycoprotein, is a component of extracellular microfibrils. *Journal of Cell Biology, 103*(6), 2499–2509.
3. Dietz, H. C., et al. (1991). Marfan syndrome caused by a recurrent de novo missense mutation in the fibrillin gene. *Nature, 352*(6333), 337–339.
4. Milewicz, D. M., Pyeritz, R. E., Crawford, E. S., & Byers, P. H. (1992). Marfan syndrome: defective synthesis, secretion, and extracellular matrix formation of fibrillin by cultured dermal fibroblasts. *Journal of Clinical Investigation, 89*(1), 79–86.
5. Chiu, H. H., Wu, M. H., Chen, H. C., Kao, F. Y., & Huang, S. K. (2014). Epidemiological profile of Marfan syndrome in a general population: A national database study. *Mayo Clinic Proceedings, 89*(1), 34–42. https://doi.org/10.1016/j.mayocp.2013.08.022
6. Arnaud, P., et al. (2021). Unsuspected somatic mosaicism for FBN1 gene contributes to Marfan syndrome. *Genetics in Medicine, 23*(5), 865–871. https://doi.org/10.1038/s41436-020-01078-6
7. Arnaud, P., et al. (2021). Clinical relevance of genotype-phenotype correlations beyond vascular events in a cohort study of 1500 Marfan syndrome patients with FBN1 pathogenic variants. *Genetics in Medicine*. https://doi.org/10.1038/s41436-021-01132-x
8. McKusick, V. A. (1955). The cardiovascular aspects of Marfan's syndrome: A heritable disorder of connective tissue. *Circulation, 11*(3), 321–342. https://doi.org/10.1161/01.cir.11.3.321
9. McKusick, V. A. (1972). *Heritable disorders of connective tissue* (4th ed.). The C.V. Mosby Company.
10. Murdoch, J. L., Walker, B. A., Halpern, B. L., Kuzma, J. W., & McKusick, V. A. (1972). Life expectancy and causes of death in the Marfan syndrome. *New England Journal of Medicine, 286*(15), 804–808.
11. Pyeritz, R. E., & McKusick, V. A. (1979). The Marfan syndrome: Diagnosis and management. *New England Journal of Medicine, 300*(15), 772–777.

12. Silverman, D. I., et al. (1995). Life expectancy in the Marfan syndrome. *American Journal of Cardiology, 75*(2), 157–160.
13. Finkbohner, R., Johnston, D., Crawford, E. S., Coselli, J., & Milewicz, D. M. (1995). Marfan syndrome: Long-term survival and complications after aortic aneurysm repair. *Circulation, 91*(3), 728–733.
14. Finkbohner, R., Johnston, D., Crawford, E. S., Coselli, J., & Milewicz, D. M. (1995). Marfan syndrome: Long-term survival and complications after aortic aneurysm repair. *Circulation, 91*(4), 728–733.
15. Pyeritz, R. E. (2019). Marfan syndrome: Improved clinical history results in expanded natural history. *Genetics in Medicine, 21*(7), 1683–1690. https://doi.org/10.1038/s41436-018-0399-4
16. den Hartog, A. W., et al. (2015). The risk for type B aortic dissection in Marfan syndrome. *Journal of the American College of Cardiology, 65*(3), 246–254. https://doi.org/10.1016/j.jacc.2014.10.050
17. de Beaufort, H. W. L., et al. (2017). Aortic dissection in patients with Marfan syndrome based on the IRAD data. *Annals of Cardiothoracic Surgery, 6*(6), 633–641. https://doi.org/10.21037/acs.2017.10.03
18. Loeys, B. L., et al. (2010). The revised Ghent nosology for the Marfan syndrome. *Journal of Medical Genetics, 47*(7), 476–485. https://doi.org/10.1136/jmg.2009.072785
19. Pyeritz, R. E. (2000). The Marfan syndrome. *Annual Review of Medicine, 51*, 481–510.
20. Habashi, J. P., et al. (2006). Losartan, an AT1 antagonist, prevents aortic aneurysm in a mouse model of Marfan syndrome. *Science, 312*(5770), 117–121. https://doi.org/10.1126/science.1124287
21. Lacro, R. V., et al. (2014). Atenolol versus losartan in children and young adults with Marfan's syndrome. *The New England Journal of Medicine, 371*(22), 2061–2071. https://doi.org/10.1056/NEJMoa1404731
22. Groth, K. A., et al. (2015). Prevalence, incidence, and age at diagnosis in Marfan Syndrome. *Orphanet Journal of Rare Diseases, 10*(1), 153. https://doi.org/10.1186/s13023-015-0369-8

POLYPYRROLE STRUCTURE AND ITS APPLICATIONS IN SUPERCAPACITORS

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Abstract:

Polypyrrole (PPy) is a versatile conductive polymer with a unique conjugated molecular structure that enables efficient charge transport and electrochemical activity. Its backbone, formed by polymerized pyrrole rings, exhibits a high degree of π-electron delocalization, which imparts significant electrical conductivity, especially in its doped state. The ease of synthesis, tunable properties, and environmental stability of PPy make it a leading material in the development of supercapacitors. In supercapacitors, PPy serves as an efficient electrode material due to its pseudocapacitive behavior, which arises from reversible redox reactions at the polymer-electrolyte interface. This capability results in high energy and power densities, positioning PPy as a key player in advanced energy storage technologies. This book chapter delves into the molecular structure and its electrochemical mechanisms in supercapacitors.

Introduction to Polypyrrole:

Polypyrrole (PPy) is a conductive polymer that has attracted significant interest in the fields of energy storage and conversion due to its excellent electrochemical properties, environmental stability, and ease of synthesis [1-3]. It is a part of a class of polymers known as conjugated polymers, which exhibit electrical conductivity as a result of the delocalized electrons in their conjugated π-bond system.

Polypyrrole is synthesized through the oxidative polymerization of pyrrole monomers [4]. The unique combination of electronic conductivity, mechanical flexibility, and chemical stability makes PPy an ideal material for a range of applications, particularly in energy storage systems such as supercapacitors, batteries, and electromagnetic shielding. In this chapter, we will explore the structural characteristics of polypyrrole, its electrochemical properties, and its promising applications in supercapacitors, a rapidly growing area of research in energy storage.

The repeating unit of pyrrole (C_4H_5N) makes up polypyrrole, the polymerization result of the monomer pyrrole. It has a heterogeneous ring-like structure that allows electrons to move around, making it a heterocyclic aromatic molecule. Because of its high conductivity, superior stability, and ease of manufacture, PPy is the conducting polymer that is most thoroughly explored by numerous research organizations. Gas sensors, supercapacitors, solar cells, biosensors, and pH sensors are just a few of the numerous applications that use PPy because of its intriguing qualities [5-7]. Both chemical and electrochemical methods can be used to create the conducting polymers. When an appropriate voltage or current is delivered to the electrode that has been submerged in the electrolyte, electrochemical polymerization takes place.

Synthesis of polypyrrole (PPy)

The synthesis of polypyrrole (PPy) can be achieved through two primary methods: electrochemical and chemical polymerization.

Electrochemical polymerization offers several advantages over chemical polymerization, making it a preferred technique in synthesizing conductive polymers like polypyrrole (PPy). The process directly produces an electroactive film attached to the electrode surface, ensuring high conductivity and strong adhesion. Additionally, the charge yield approaches 100%, enabling precise control over the mass and thickness of the resulting film. Moreover, the properties of the film can be finely tuned by varying the preparative conditions, such as applied potential, current density, or electrolyte composition. Electropolymerization of pyrrole involves applying an anodic potential or current to a conducting substrate immersed in an electrolyte containing the pyrrole monomer and a doping salt. Various electrodeposition techniques, including pulse galvanostatic, potentiostatic, and potentiodynamic methods, have been explored for PPy synthesis. For instance, pulse galvanostatic methods have been employed to deposit PPy thin films for supercapacitor applications [8], while potentiostatic deposition has been used to achieve controlled film growth [9]. Potentiodynamic methods, such as cyclic voltammetry, enable the synthesis of films with tailored properties. Recent advancements include the use of pre-hydrolyzed alkoxysilanes to enhance the adhesion of PPy films to indium–tin oxide electrodes, improving their durability [10]. Additionally, electropolymerization continues to be pivotal in energy storage applications, with studies emphasizing its role in producing battery materials with tunable properties. These

developments highlight the versatility and precision of electrochemical polymerization in creating functional conductive polymer films.

Conversely, chemical polymerization involves the direct reaction of pyrrole monomers with an oxidizing agent in a suitable solvent, leading to the formation of PPy through a similar oxidation and chain growth mechanism [11]. Common oxidizing agents used in chemical polymerization include ferric chloride, ammonium persulfate, and potassium dichromate. Both methods offer distinct advantages and disadvantages, with electrochemical polymerization providing greater control over film thickness and morphology, while chemical polymerization offers simplicity and scalability. The choice of method depends on the desired properties of the PPy and the specific application requirements.

Applications of PPy in supercapacitor

Polypyrrole (PPy) has garnered significant attention as a high-performance electrode material for supercapacitors due to its intrinsic conductivity, environmental stability, and ease of synthesis. Recent advances have focused on improving the energy density, stability, and flexibility of PPy-based supercapacitors [12]. For instance, the integration of nanostructures like carbon nanotubes (CNTs) and PPy in core–shell architectures has significantly enhanced charge transport and surface area, leading to increased energy storage capacity. Similarly, the development of composite materials combining PPy with metal oxides, such as manganese dioxide, or graphene oxide has been shown to improve cycling stability and specific capacitance.

Furthermore, novel substrate designs, including the use of dispersed buckypaper tape (DBPT), have demonstrated improved mechanical flexibility and superior areal capacitance, with DBPT-based supercapacitors achieving 88.3% capacitance retention after 1,000 bending cycles[13]. Optimizing the electrolyte composition, particularly with ionic liquids or redox-active electrolytes, has also contributed to enhanced energy density and long-term stability. These advancements underscore the potential of PPy in high-performance energy storage applications, including portable electronics, electric vehicles, and flexible devices.

Conclusion:

Polypyrrole is a promising material for use in supercapacitors due to its unique electrochemical properties, including high capacitance, fast charge/discharge rates, and excellent stability. Its conjugated structure and doping capabilities enable it to store energy

efficiently, making it ideal for energy storage applications. As research continues to optimize polypyrrole's performance, particularly through composite materials and nanostructuring, its role in the development of high-performance, sustainable supercapacitors is expected to grow significantly.

References:

1. Kim, M. S., Moon, J. H., Yoo, P. J., & Park, J. H. (2012). Hollow polypyrrole films: Applications for energy storage devices. *Electrochemical Society*, *159*, A1052.
2. Shi, Y., Peng, L., Ding, Y., Zhao, Y., & Yu, G. (2015). Nanostructured conductive polymers for advanced energy storage. *Chemical Society Reviews*, *44*, 6684–6696.
3. Gharahcheshmeh, M. H., & Chowdhury, K. (2024). Fabrication methods, pseudocapacitance characteristics, and integration of conjugated conducting polymers in electrochemical energy storage devices. *Energy Advances*, *3*, 2668–2703.
4. Ibrahim, F. A., Khalaf, A. I., & Badr, M. M. (2024). Conductive polypyrrole: Synthesis, characterization, thermal, and electrical properties for different applications. *Physica Scripta*, *99*, 065971.
5. Verma, A., Kumar, T., & Singhal, R. (2024). Silver-doped polypyrrole nanocomposite-based gas sensor for enhanced ammonia gas sensing performance at room temperature. *Chemical Physics Impact*, *9*, 100722.
6. Abdillah, O. B., Rus, Y. B., Ulfa, M., Dedi, & Iskandar, F. (2023). Recent progress on reduced graphene oxide and polypyrrole composites for high-performance supercapacitors: A review. *Journal of Energy Storage*, *74*, 109300.
7. Zhang, X., Tan, X., Wang, P., & Qin, J. (2023). Application of polypyrrole-based electrochemical biosensor for the early diagnosis of colorectal cancer. *Nanomaterials*, *13*(4), 674.
8. Zhang, J., Kong, L.-B., Li, H., Luo, Y.-C., & Kang, L. (2010). Synthesis of polypyrrole film by pulse galvanostatic method and its application as supercapacitor electrode materials. *Journal of Materials Science*, *45*, 1947–1954.
9. Scharifker, B. R., García-Pastoriza, E., & Marino, W. (1991). The growth of polypyrrole films on electrodes. *Journal of Electroanalytical Chemistry and Interfacial Electrochemistry*, *300*(1–2), 85–98.
10. Cossement, D., Plumier, F., Delhalle, J., Hevesi, L., & Mekhalif, Z. (2003). Electrochemical deposition of polypyrrole films on organosilane-modified ITO substrates. *Synthetic Metals*, *138*, 529–536.

11. Tan, Y., & Ghandi, K. (2013). Kinetics and mechanism of pyrrole chemical polymerization. *Synthetic Metals*, *175*, 183–191.
12. Sooda, Y., Singh, K., Mudil, H., Lokhande, P. E., Singh, L., Kumar, D., Kumar, A., Mubarak, N. M., & Dehghani, M. H. (2024). Insights into properties, synthesis, and emerging applications of polypyrrole-based composites, and future prospects: A review. *Heliyon*, *10*, e33643.
13. Zhou, H., Liu, S., Ren, M., & Zhai, H.-J. (2024). Highly efficient utilization of polypyrrole enabled by dispersed buckypaper tape for high-performance flexible energy storage. *Inorganic Chemistry Frontiers*, *11*, 6616–6626.

A SURVEY ON JAVA FRAMEWORK

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Abstract:

This chapter, the focus is on presenting web design frameworks as a conceptual methodology for maximizing possibilities for reuse in web applications. The discussion begins by highlighting the imperative need for constructing abstract and reusable directional design structures. Various types of web information systems are examined to underscore this necessity. The chapter then delves into Hibernate Framework technology, recognized as a unique and efficient resource for accessing extensive databases. Special attention is given to demonstrating the implementation of persistent features in object-oriented systems using Hibernate. Furthermore, the paper offers insights into design patterns and frameworks, elucidating the intricate relationship between them. Java is introduced as a platform that embraces an N-tier framework of the Model-View-Controller (MVC) model within the J2EE platform. The utilization of Enterprise JavaBeans (EJB), the Struts Web Framework, and Hibernate technology in Java is explored, emphasizing their collective role in shaping a comprehensive and efficient web application development environment.

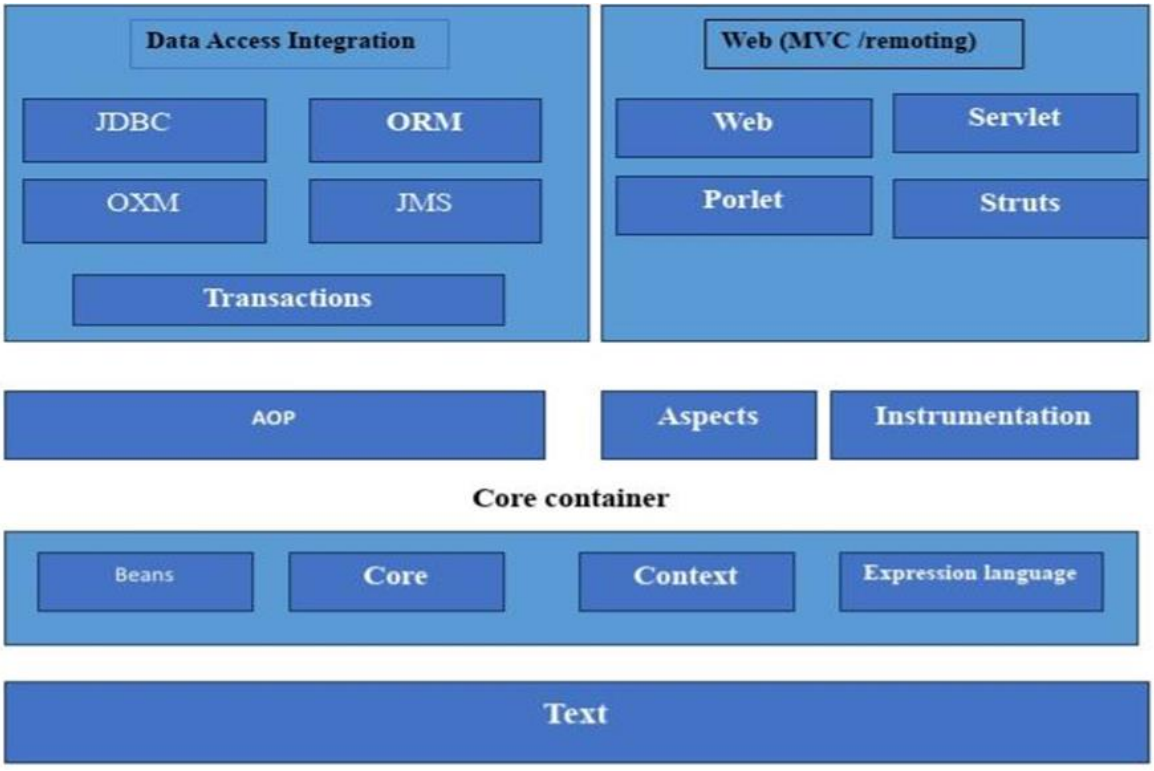
Keywords: Java Framework, Web Applications

Introduction:

Over the past decade, extensive research has been dedicated to studying the Java language within the framework of abstract understanding. The development of complex web applications, such as e-commerce applications, is recognized as a time-consuming endeavour [1]. A crucial aspect of enhancing enterprise applications involves constructing and maintaining the persistence layer responsible for gathering and retrieving objects from the chosen database. Hibernate seamlessly addresses this need, offering an easy-to-use and authoritative object-relational persistence framework for Java applications [2] Moreover, design patterns play a pivotal role in software development by aiding in the identification, naming, and abstraction of recurring problems, ultimately leading to the identification of best practice solutions. Ongoing research in testing concurrent Java programs encompasses

various tools and techniques, including static analysis, dynamic analysis, model checking, and their combinations [3]. This chapter aims to introduce a practical library and approach for model-checking Java programs, ensuring the validation of simultaneous components without the need for installing additional complex tools. The applicability of this method in current industrial and commercial settings is demonstrated [4]. The Spring Framework emerges as a significant player, providing a comprehensive programming and configuration model for modern Java-based enterprise applications across diverse deployment platforms. Notably, spring focuses on the infrastructure support at the application level, streamlining the "plumbing" of enterprise applications. This approach enables development teams to concentrate on application-level business logic without unnecessary dependencies on specific deployment environments [5].

Spring Framework Architecture

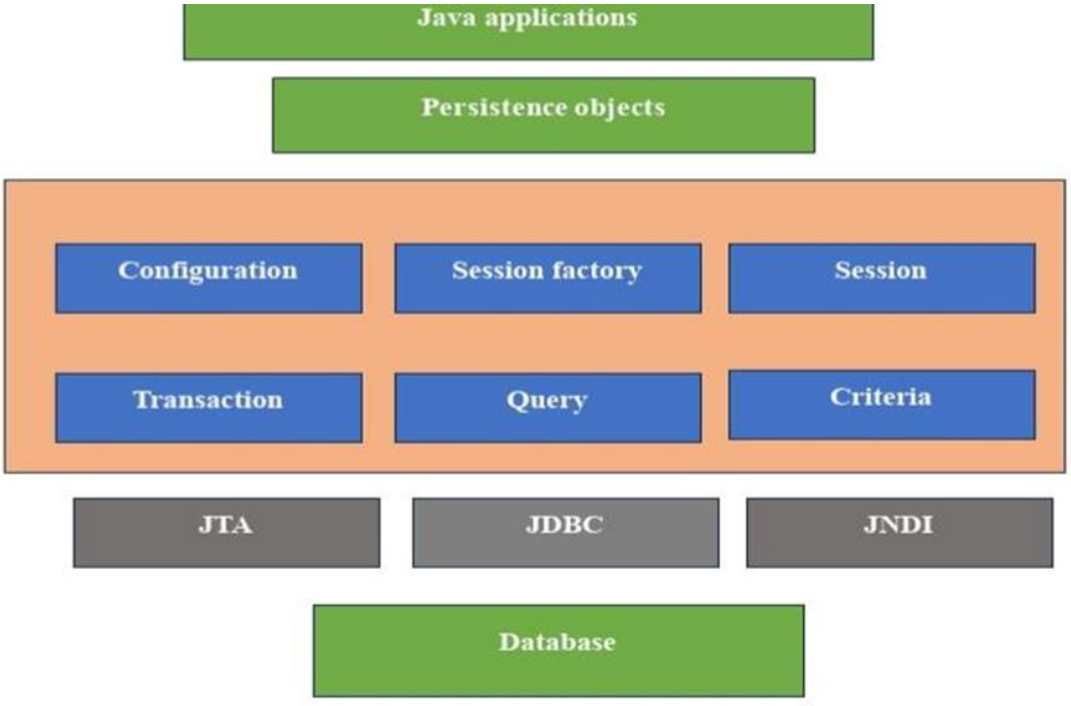


The Spring Framework provides comprehensive solutions for Java-based applications across all layers, accommodating various architectural needs, including one-tier standalone Java applications, web-tier components within web applications, and enterprise-tier functionalities involving Enterprise Java Beans (EJB). With a modular architecture, the Spring Framework encompasses around 20 distinct modules, each tailored to address specific aspects of application development.[6] These modules can be

selectively utilized based on the unique requirements of an application, offering a flexible and modular approach to building robust and scalable Java applications.

The architecture of the Spring Framework is structured, beginning with the Core Container and progressing to Data Access Integration and Web MVC components. The Core Container comprises crucial modules, including Core, Beans, Context, and Expression Language. The Core Module facilitates dependency injection features, enhancing the management of object dependencies, while the Bean Module implements the Bean Factory Pattern, contributing to efficient bean instantiation and configuration. The Context module builds upon the foundation laid by the Core and Beans modules, providing a medium to access objects defined and configured within the application. Serving as an intermediary layer, it streamlines the interaction with various components. The Expression Language module introduces a robust expression language capable of dynamically querying and controlling the object graph during runtime, adding flexibility to the application architecture. In the Data Access/Integration layer, modules such as JDBC, ORM, OXM, and JMS collectively address data access and integration concerns, ensuring seamless interactions with databases and external systems. Lastly, the Web layer encompasses modules like Web, Web-Servlet, Web-Struts, and Web-Port let, playing a pivotal role in web application development by handling request processing and providing support for popular web frameworks such as Struts and Portlet.

Hibernate Framework Architecture



This framework simplifies the complexities and challenges associated with handling JDBC and SQL data manipulation. Proficiently mapping Java classes to database tables, it streamlines the interaction between Java applications and databases.[9] Known for its effective database integration, this framework is widely employed in scenarios where seamless connectivity with databases is essential for optimal application performance.

Java Framework Advantages

Various frameworks have been proposed to establish a comprehensive framework for video analysis methodologies implemented in software. The landscape of Java-based web development has been inundated with a myriad of frameworks, each serving distinct purposes. It's been quite some time since I've observed the development of a web application without the reuse of any framework. Whatever the requirement, there exists a Java framework tailored to address it. Interestingly, there might be two or three frameworks accomplishing similar tasks. In this chapter, we delve into the framework-centric approach to development, examining some of the widely recognized Java web frameworks currently available.[10]

Spring Framework:

Spring Offers Aspect-Oriented Programming (AOP) capabilities, addressing the separation of concerns at a broader level. This framework empowers developers to incorporate features like transactions, security, database connectivity components, and logging components seamlessly at the declaration level. By leveraging dependency injection and Inversion of Control [11] Spring mitigates the coupling between different modules. At runtime, Spring handles the provision of input parameters required for method contracts, contributing to a more modular and loosely coupled application architecture.

Conclusion:

In this chapter, I have introduced an innovative abstract interpretation framework with a generic application to the Java programming language. Spring, within this context, provides a robust approach to managing business objects, encouraging best practices such as programming to interfaces rather than concrete classes. The chapter extends its focus by delving into the broader functional module of document management, leveraging advanced concepts of life cycle management. Both Spring and Struts contribute significantly to the development, debugging, and testing processes, offering valuable support to users engaged in software-related activities.

References:

1. Vasavi, Y. V., Sreevani, Y. V., & Priya, G. (2011). Hibernate technology for an efficient business application extension. *Journal of Global Research in Computer Science, 2*(6), 118–125. Retrieved from www.jgrcs.info
2. Mane, D., & K. C. (2013). The Spring Framework: An open-source Java platform for developing robust Java applications. *International Journal of Innovative Technology and Exploring Engineering (IJITEE, 3*(2), 138–143.
3. Iakovidis, D. K., & D. D. (2014). Open-access framework for efficient object-oriented development of video analysis software. *Journal of Software Engineering and Applications, 7*(8), 730–743. https://doi.org/10.4236/jsea.2014.7808
4. Furtună, C. F. (2006). Enterprise application integration using Java technologies. *Revista Informatica Economică*, 9–17.
5. Ni, J., & Z., L. (2007). A study of document management system based on J2EE. *Modern Applied Science, 1*(3), 2–5. Retrieved from www.csenet.org/mas.html
6. Long, B. (2009). A framework for model checking concurrent Java components. *Journal of Software, 4*(8), 867–874. https://doi.org/10.4304/jsw.4.8.867-874
7. Jurišić, M., & K., D. (2014). Application framework development and design patterns: Current state and prospects. *Central European Conference on Information and Intelligent Systems*, 306–344.
8. Munsi, N., & S., N. (2014). Integration of Struts, Spring, and Hibernate for an e-commerce system. *International Journal of Computer Science and Mobile Computing, 3*(10), 853–859. Retrieved from www.ijcsmc.com
9. Oak, H. (2003). Choose the best Java framework for your application. Retrieved from http://www.techrepublic.com/article/choose-the-best-java-framework-for-your-application
10. Forax, R., & D., E. (2005). A reflective implementation of Java multi-methods. *IEEE Transactions on Software Engineering*, 1–14.
11. Schwabe, D., Rossi, G., & Esmeraldo, L. (2001). Web design frameworks: An approach to improve reuse in web applications. In Y. D. San Murugesan (Ed.), *Web Engineering (Managing Diversity and Complexity of Web Application Development)* (pp. 335–352). https://doi.org/10.1007/3-540-45144-7_32

ASSOCIATION OF QUADRICEPS ANGLE (Q-ANGLE) WITH ANTHROPOMETRIC MEASUREMENTS IN HEALTHY YOUNG ADULTS

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Abstract:

Background: Quadriceps angle is the angle produced between the quadriceps muscle and the patellar tendon, which is also known as Q angle. It is also regarded as a key component for the correct knee posture and movement. Q angle is frequently employed as a diagnostic indicator for knee-related issues such as anterior knee pain, degenerative knee disorders, osteoarthritis etc. It has a great clinical and biomechanics significance and this angle gives useful information about alignment of lower limb. Present study shows association of Q angle with gender, various anthropometric measurements and Quadriceps muscle strength.

Methods: Total 150 healthy young individuals (20 male and 130 female) between the age of 18 to 30 years from the different constituent institutes of Sumandeep Vidyapeeth University were included in the study. Q angle was measured in degrees by using universal goniometer on both sides. Anthropometric measurements - Height, weight. Body mass index, Waist and Hip circumference, Intercondylar distance between femur were measured.

Results: In this study, the correlation between Q angle and Anthropometric measurements were analyzed. The mean Q angle on right side was 18.87 and on left side was 18.87. Bilaterally, no significant differences were found in Q angle. The angle of right and left side was significantly correlated with intercondylar distance. However, these angles are not correlated with WHR.

Conclusion: This study supported positive correlation of weight and BMI with Q angle; negative correlation of height, intercondylar distance of femur and although, no significant correlation was found between Q angle and WHR.

Keywords: Q angle, Anthropometric measurements, Quadriceps muscle strength

Introduction:

Quadriceps angle is the angle produced between the quadriceps muscle and the patellar tendon, which is also known as Q angle [1]. It is measured between a line connecting the anterior superior iliac spine to the mid-point of patella and the tibial tuberosity to the mid-point of patella.

This angle is regarded clinically as a very significant anatomical vector that shows the biomechanical effect of the quadriceps muscle on the knee. It is also regarded as a key component for the correct knee posture and movement [2]. In the frontal plane, the patellar tendon works as information relay center about the net force generated by quadriceps muscles. The net effect of the pull of the quadriceps and the patellar alignment can be assessed clinically using a measurement called the Q-angle [3]. The Q angle is frequently employed as a diagnostic indicator for knee-related issues such as anterior knee pain, degenerative knee disorders, osteoarthritis etc. [1,3].

Normal value of Q angle is between 130 to 180. In male it is 130 and in female it is 180 [2,3]. A higher Q angle is indicative of pathological lateral forces on the patella. Although a very large Q angle is usually an indicator of some structural malalignment [3,4]. Large Q angle create excessive lateral forces on the patella that make the patella susceptible to pathologic changes. The patella may actually subluxate or dislocate over the femoral sulcus in the result of an excessive lateral strain. The patella may really subluxate or dislocate over the femoral sulcus in the event of a strong lateral strain. As a result, the lateral portion of the femoral sulcus may experience additional lateral patellar compression, which can be detrimental. The Q-angle may result in an incorrect estimate of the lateral force on the patella if there is a significant imbalance between the vastus medialis and vastus lateralis muscles in a patient because the quadriceps muscle's actual pull is no longer along the estimated line. Smaller Q angles are produced by patella that sit improperly lateral in the femoral sulcus as an outcome of uneven stresses, because they are better aligned with the ASIS and tibial tuberosity. There are some abnormalities that may produce more lateral forces. There is a possibility of imbalance between the vastus lateralis and vastus medialis muscles. Although, as identified earlier, this imbalance cannot be measured inside. The patellar movement may restrict and undergo stress when mobility of inter trochanteric band is compromised. This causes medial shift while knee flexion and facets of patella are remained under stress. When the IT band moves posteriorly with knee flexion, it applies greater lateral pull on the patella which results in a higher lateral tilting

as knee flexion increases. The increased lateral tilt could, increasing joint stress.4 Thus, it is considered as an important factor of patellofemoral function and dysfunction. It is a risk factor for patellofemoral pain, patellar subluxation and dislocation [5,6,7].

Women have larger quadriceps angle values than males when comparing the two genders. Women have a broader pelvis, shorter femur length and a more inwardtwisting femur which lead to this difference [8]. Many studies show the relation between Q angle and body mass index. Body mass index is calculated by measurement of weight (in kilograms) and height (in meters) [3]. The height and weight of human body directly or indirectly affect the Q angle. Some studies shows that as height increases, the quadriceps angle decreases. Some studies shows that if weight is higher, then the Q angle is also high. Female have greater Q angle when compared with male, with respect of their body weight.

Waist hip ratio is a measurement of waist circumference and hip circumference. Which give information about fat stored on body in the waist and hip areas which may affect the Q angle [3,9]. Females with higher hip and waist diameters and high Q-angle values may have higher levels of body fat in their lower bodies. Intercondylar distance between femur shows effect on Q angle. When Q angle increases, it shows decrease in the distance between medial condyle of femur which leads to genu valgum. When Q angle decreases, there is more distance between medial condyle of femur which leads to genu varum [4,10,11]. In some cases, there is also a possibility of no distance between medial condyles due to fatty area. Muscle strength is an important indicator of muscle performance [12,13]. It is the quantity of force; a muscle can generate with one largest exertion. Both the hip flexors and extensors of the knee make up the quadriceps muscle group. Rectus Femoris, Vastus Medialis, Vastus Lateralis and Vastus Intermedius are its four separate muscles. The quadriceps muscle is essential for daily activities like climbing stairs, getting up from chair etc. [12,13]. The quadriceps muscle controls the amount of knee flexion during initial contact (loading response) and then extends the knee toward midstance. It again controls the amount of flexion during pre-swing (heel-off to toe-off) and prevents excessive heel rise during initial swing. With a lack of quadriceps work, the patient either twists the limb outward to lock the knee or tilts the trunk forward while initial contact to shift the center of gravity in front to the knee so it is stable. Fast walking may cause an excessive amount of heel rise during the initial swing [12]. Age, body mass index, nutritional factors and physical activity level are the variables that determine the quadriceps muscle strength [14].

Since the quadriceps angle reflects the effect of the quadriceps mechanism on the knee, it is an accepted medical fact that this measurement is a very significant indicator of the biomechanical function in the lower extremity [1,15,16]. The importance of Q angle in assessing knee joint function and determining an individual's knee health has come to be accepted [17]. Q angle measurement gives useful information about how the pelvis, leg, and foot may be aligned. Uneven alignment may have an impact on the knee's efficacy [1,18,19].

Procedure:

After obtaining the ethical approval, healthy individuals were approached and explained the study. All those who were willing to participate in study were requested to fill out Informed Consent Form (Annexure I). A Participant Information Sheet (Annexure II) was given to each participant and they were explained regarding the assessment involved in the study. All the participant were screened as per the assessment sheet (annexure III). Participants who were falling under the exclusion criteria were excluded from the study. All those participants who fulfill inclusion criteria were explained detail about the entire study procedure in their language and they were recruited in the study. Those subjects who were recruited for the study, their anthropometric measurement (Height, weight, west and hip circumference and intercondylar distance) were taken. After that quadriceps angle and quadriceps muscles strength were assessed.

1. **Measurement of Height and Weight:** The subjects were asked to remove his/her foot ware. Subject's weight was recorded in kilograms and height was noted in meters for each individual using weighing scale and stadiometer [3,5,13,28]. Body mass index (BMI) of the subject was calculated, using the formula; BMI = Height (m)2 / Weight (kg). BMI was classified in different categories according to WHO guidelines. Here, BMI was classified in 4 categories, in which <18.5 is underweight, 18.5 to 24.9 is normal, 25.0 to 29.9 is pre obese and 30.0 to 34.9 is obese class 1 [23].
2. **Measurement of Waist Hip Ratio (WHR):** The individual was instructed to stand with their feet together, their arms at their sides, and their body weight equally distributed while measuring their waist to hip ratio. The subject should be relaxed I [8,28]. For the measurement of Waist circumference, the non-stretchable measure tape was used which was kept at the level of umbilicus and measurement was taken at the end of a normal expiration, when the lungs are at their functional residual capacity [29]. II. For the measurement of hip circumference, the non-stretchable

measure tape was used which was kept at the level of the widest portion of the buttocks with the tape parallel to the floor [29]. WHR was calculated, using the following formula;

Waist circumference WHR = Waist circumference / Hip circumference.

This procedure was repeated three times and the mean value was noted.

3. **Measurement of Intercondylar distance:** For measuring intercondylar distance, I. Subject was asked to lie down in supine lying position. Then both the knees were kept in resting position, medial knee joint line was palpated and then the most prominent portion i.e. medial femoral condyle was marked both the sides. II. Then the subject was asked to assume erect sanding position in a way that both patella face forward and the medial aspects of the knees and medial malleoli of both limbs are as close together as possible.10,30 The distance between both the medial femoral condyles were measured using digital vernier caliper. This procedure was repeated three times and the mean value was noted.
4. **Measurement of Quadriceps angle (Q angle):** For measuring Q angle, the subject was asked to wear short trouser so that the landmarks were exposed and marked. The subject was asked to lie down in supine lying position by keeping both the lower limb in neutral position [3,31,32]. Palpation and marking of landmarks: I. The most prominent part located at anterior aspect of pelvic bone, known as Anterior Superior Iliac Spine (ASIS) was palpated and marked. II. To mark center of patella, the subject was asked to relax. All the borders of patella were palpated and the center point of the same was marked. III. To mark tibial tuberosity, the shin of tibia was traced with the help of the thumb. The most prominent portion located at the insertion of patella tendon was marked. Measurement of Q angle: In order to measure it, the lines were drawn to connect the markings of I. ASIS and center of patella II. Tibial tuberosity and center of patella A Universal goniometer (made up of plastic and transparent material with mid line marking on the arms) was used to measure the Q angle. The fulcrum of goniometer was placed over the center of patella and the marking of both arms of the goniometer were placed over the lines drawn and the angle was measured.8 This procedure was repeated three times and the mean value was noted, it was performed both the sides.

Results and Discussion:

150 participants were recruited in the present study with a mean age of 23 years.

The study aimed to observe the association of Q angle with gender, anthropometric measurements and quadriceps muscle strength in healthy young adults. In this study, out of 157 subjects, 150 were recruited and 7 were excluded due to not matching the inclusion criteria and denied to complete full procedure. The Q angle is one of the crucial clinical parameters which helps in evaluating Both in terms of athletic performance and the diagnosis of many conditions related to knee joint. It also helps in evaluating the quadriceps forces, patellofemoral joint-related factors and knee alignment. Any alignment change that increases the Q angle which can be harmful as an increase in this lateral force can lead the lateral patella to get more contracted.

Quadriceps angle and Gender:

In present study, a significant correlation was found between Q angle and gender.

This was supported by previous studies which are as follows:

Ramada R. Khasawneh *et al.* (2019) showed that in contrast to men, women had a larger Q angle. In that study, the absolute difference in Q angle between young men and young women was measured using a goniometer, and it was discovered that the difference was 3.25 higher in females than in boys. Additionally, both sexes had considerably larger Q angle values. As the outcome of having a wider pelvis than men, which can be extrapolated by having a greater distance between the pelvis and the patella than between the patella and the tibial tuberosity, women may have higher Q angle values. This may cause an alteration in the position of the anterior superior iliac spine, which has a significant effect on the Q angle values [1].

Quadriceps angle and height:

In present study, it was found that Q angle and height was significantly correlated. Along with this it was found that as the height of the subject is inversely proportional to Q angle. The above findings are supported by previous study which is as follows:

Ramada R. Khasawneh *et al.* (2019) showed significant correlation between height and Q angle. The same was also supported by other study which was done by Jaiyesimi *et al.* (2009). The possible reason behind these findings is due to the fact that taller people often have a smaller Q angle due to the fact that men likely to be taller compared to women.4 Results of the investigation further supported the notion that taller people had significantly smaller Q angles on both genders.

Quadriceps angle and Body Mass Index:

In this study, it was found that Q angle and BMI have significant correlation, which was positively correlated with each other. This finding is supported by previous study which are as follows:

Anand Heggannavar *et al.* (2016) concluded that due to increased body mass, people have greater absolute knee adduction moments which was compensated by slow walking gait and increased toe outing gait. With this femoral anteversion occurs which may lead to medial rotation of femur and it displaced patella medially. So due to that, in toing of gait is compensated with external rotation of tibia and this increased tibial external rotation leads to greater Q angle [23]. That the Q angle increased with increased tibial external rotation and so the load of weight bearing joint was increased.

Quadriceps angle and Intercondylar distance of femur:

In present study, significant correlation was found between Q angle and intercondylar distance of femur. The above findings are supported by previous studies which are as follows:

An increase in the normal tibiofemoral angle results in genu valgum or knock knees. A decrease in the normal tibiofemoral angle results in genu varum or bow legs [4].

According to Hassan Daneshmandi (2011), the Q angle's magnitude and the lower extremity's alignment are related. Along with the tibiofemoral angle had the strongest association with greater Q angle. These finding support that the peculiarities of lower extremity alignment may alter where the anatomical markers used to calculate the Q angle are located. The results indicated that Q angle and tibiofemoral angle were related. Increased the patella would be moved medially in relation to the anterior superior iliac spine by the tibiofemoral angle, which symbolizes the valgus angle created by the anatomical axes of the femur and tibia and tibial tuberosity laterally, thus increasing Q angle. In addition to aberrant transverse plane motions, the patellofemoral joint can also be affected by excessive frontal plane motions. Most significantly, valgus at the knee might widen the Q angle because the patella would move medially in relation to the ASIS. In contrast, a varus angle of the knee might reduce the Q angle since it would bring the patella closer to the ASIS.

Quadriceps angle and Waist Hip Ratio (WHR):

In present study, Q angle showed no significant correlation with WHR. Some previous studies showed significant correlation between these two, which are as follows: A

study by Ved Prakash *et al.* (2017) and Atif Maqsood (2022), stated that there is significant correlation between WHR & Q-angle. It means that if there is increase in WHR, substantially there is reduction in Q-angle [39]. Waist hip ratio shows the proportion of fat stored in body in the waist & hip areas. Most people have body fat distribution in two ways in which one is around the middle of the body known as apple shaped while another one is around the hip known as pear. According to the World Health Organization, abdominal obesity is indicated by a waist-hip ratio that is greater than 0.90 for men and 0.85 for women, or by a body mass index that is greater than 30.0. According to the National Institute of Diabetes, Digestive and Kidney Diseases, men and women who have a waist-to-hip ratio greater than 1.0 are at an elevated risk for health problems because of their fat distribution. The findings of this investigation indicated a negligible positive connection between WHR and BMI in OA knees. WHR and Q angle revealed a weakly negative correlation,3 which suggests that as WHR increases, Q-angle will fall [39].

Conclusion:

In conclusion, the present study provided information of correlation between Q angle, gender, anthropometric measurements. This study supported positive significant correlation of weight and BMI with Q angle, negative correlation of height, intercondylar distance of femur with Q angle. Also, the study reported no significant correlation between Q angle and WHR.

References:

1. Khasawneh, R. R., Allouh, M. Z., & Abu-El-Rub, E. (2019). Measurement of the quadriceps (Q) angle with respect to various body parameters in young Arab population. *PLoS ONE, 14*(6), e0218387. https://doi.org/10.1371/journal.pone.0218387
2. Magee, D. J. (2013). *Orthopedic Physical Assessment-E-Book.* Elsevier Health Sciences.
3. Prakash, V., Sahay, P., & Satapathy, A. (2017). Correlation between body mass index, waist-hip ratio, and quadriceps angle in subjects with primary osteoarthritic knee. *International Journal of Health Sciences and Research, 7*(6), 197–205.
4. Levangie, P. K., & Norkin, C. C. (2011). *Joint structure and function: A comprehensive analysis.* F.A. Davis.
5. Tarawneh, I., Al-Ajoulin, O., & Alkhawaldah, A. (2016). Normal values of quadriceps angle and its correlation with anthropometric measures in a group of Jordanians. *Journal of Royal Medical Services, 23*(2), 53–58.

6. Raveendranath, V., Nachiket, S., Sujatha, N., Priya, R., & Rema, D. (2009). The Quadriceps angle (Q angle) in Indian men and women. *European Journal of Anatomy, 13*(3), 105–109.
7. Raveendranath, R., Nachiket, S., Sujatha, N., Priya, R., & Rema, D. (2011). Bilateral variability of the quadriceps angle (Q angle) in an adult Indian population. *Iranian Journal of Basic Medical Sciences, 14*(5), 465.
8. Raizada, A., Shruthy, K. M., Takiar, R., & Bhuvanesh, S. (2019). Changes in quadriceps angle (Q-angle) with regard to gender and different anthropometric parameters. *International Journal of Anatomy Research, 7*(3.1), 6756–6761.
9. Maqsood, A. (2022). Evaluation of quadriceps angle and waist-hip ratio in relation to body mass index among multiparous women. *Global Drug Design & Development Review, 7*(1), 11–17.
10. Oderinde, I. (n.d.). Association between intercondylar/intermalleolar distances and tibiofemoral angles: A cross-sectional study.
11. Ekim, A. A., Hamarat, H., & Musmul, A. (2017). Relationship between Q-angle and articular cartilage in female patients with symptomatic knee osteoarthritis: Ultrasonographic and radiologic evaluation. *Archives of Rheumatology, 32*(4), 347–352.
12. Kisner, C., Colby, L. A., & Borstad, J. (2017). *Therapeutic exercise: Foundations and techniques.* F.A. Davis.
13. Onuorah, O. C., Agha, M. M., Mong, E. U., John, D. O., Dim, P. A., Ahanonu, O., & John, J. N. (n.d.). Relationship of quadriceps femoris muscle strength and endurance with selected anthropometric indices.
14. Saç, A., & Taşmektepligil, M. Y. (2018). Correlation between the Q angle and the isokinetic knee strength and muscle activity. *Turkish Journal of Physical Medicine and Rehabilitation, 64*(4), 308.
15. El Gharib, M. H., El Tohamy, A. M., & Mohamed, N. E. (2021). Determining the relationship between the quadriceps and tibiofemoral angles among adolescents. *Journal of Taibah University Medical Sciences, 16*(1), 70–76.
16. Tsakoniti, A. E., Mandalidis, D. G., Athanasopoulos, S. I., & Stoupis, C. A. (2011). Effect of Q-angle on patellar positioning and thickness of knee articular cartilages. *Surgical and Radiologic Anatomy, 33,* 97–104.
17. Sener, O. A., & Durmaz, M. (2019). Effect of sport training and education on Q-angle in young males and females. *Journal of Education and Training Studies, 7*(7), 17–21.

18. Shiva Prakash, S., Choudhary, M., & Manjappa, C. (2019). Influence of gender and bilateral variability of the quadriceps angle (Q angle) among adults. *International Journal of Orthopaedic Sciences, 5*(2), 688–691.
19. Mohanty, N. R., Tiwari, A., & Koley, S. (2019). Bilateral correlation of Q-angle with selected lower extremity biomechanical alignment variables in state-level female basketball players. *European Journal of Physical Education and Sport Science,* 2019.
20. Madhu, G. R., & Keshavamurthy, T. (n.d.). An analysis of Q-angle with respect to various body parameters in athletes.
21. Mohanty, N. R., Tiwari, A., & Koley, S. (2019). Study on anthropometric and biomechanical characteristics of lower extremities and their effects on quadriceps angle magnitude in young males. *Age (years)*, *18*, 28-00.
22. Pooja, G., Anushree, G., Neha, T., & Surendra, W. (2017). Comparison of the effect of DeLorme and MacQueen strengthening protocol for improving quadriceps muscle strength in normal female individuals. *International Journal of Physiotherapy Research*, *5*(3), 2127-2132.
23. Heggannavar, A., Battula, L., & Metgud, S. (2016). A correlation between leg-heel alignment, tibial torsion, and Q angle amongst normal, overweight, and obese individuals. *International Journal of Physiotherapy Research*, *4*(3), 1530-1534.
24. Daneshmandi, H., Saki, F., Shahheidari, S., & Khoori, A. (2011). Lower extremity malalignment and its linear relation with Q angle in female athletes. *Procedia - Social and Behavioral Sciences*, *15*, 3349-3354.
25. Nguyen, A. D., Boling, M. C., Levine, B., & Shultz, S. J. (2009). Relationships between lower extremity alignment and the quadriceps angle. *Clinical Journal of Sport Medicine*, *19*(3), 201-206.
26. Herrington, L., & Nester, C. (2004). Q-angle undervalued? The relationship between Q-angle and medio-lateral position of the patella. *Clinical Biomechanics*, *19*(10), 1070-1073.
27. Tan, K. C. (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *The Lancet*.
28. Andreacchi, A. T., Griffith, L. E., Guindon, G. E., Mayhew, A., Bassim, C., Pigeyre, M., Stranges, S., & Anderson, L. N. (2021). Body mass index, waist circumference, waist-to-hip ratio, and body fat in relation to health care use in the Canadian Longitudinal Study on Aging. *International Journal of Obesity*, *45*(3), 666-676.
29. World Health Organization. (2008). *Waist circumference and waist-hip ratio: Report of a WHO expert consultation, Geneva, 8-11 December 2008*.

30. Do, T. T. (2001). Clinical and radiographic evaluation of bowlegs. *Current Opinion in Pediatrics*, *13*(1), 42-46.
31. Ali, M. F., Fayed, I. H., Elwardany, S. H., & Alenzi, A. S. (2023). Hamstring to quadriceps muscle torque ratio in adult females with anterior knee pain. *Journal of Pharmaceutical Negative Results*, *201-208*.
32. Smith, T. O., Hunt, N. J., & Donell, S. T. (2008). The reliability and validity of the Q-angle: A systematic review. *Knee Surgery, Sports Traumatology, Arthroscopy*, *16*, 1068-1079.
33. Sabino, G. S., Felício, D. C., Guimarães, C. Q., Abreu, B. J., & Vieira, W. H. (2016). Validity analysis of one-repetition maximum strength test for determining the hamstrings-to-quadriceps ratio. *Motriz: Revista de Educação Física*, *22*, 133-137.
34. Seo, D. I., Kim, E., Fahs, C. A., Rossow, L., Young, K., Ferguson, S. L., Thiebaud, R., Sherk, V. D., Loenneke, J. P., Kim, D., & Lee, M. K. (2012). Reliability of the one-repetition maximum test based on muscle group and gender. *Journal of Sports Science and Medicine*, *11*(2), 221-225.
35. McNair, P. J., Colvin, M., & Reid, D. (2011). Predicting maximal strength of quadriceps from submaximal performance in individuals with knee joint osteoarthritis. *Arthritis Care & Research*, *63*(2), 216-222.
36. de Souza Jr., T. P., Fleck, S. J., Simão, R., Dubas, J. P., Pereira, B., de Brito Pacheco, E. M., Da Silva, A. C., & de Oliveira, P. R. (2010). Comparison between constant and decreasing rest intervals: Influence on maximal strength and hypertrophy. *The Journal of Strength & Conditioning Research*, *24*(7), 1843-1850.
37. Ahtiainen, J. P., Pakarinen, A., Alen, M., Kraemer, W. J., & Häkkinen, K. (2005). Short vs. long rest periods between the sets in hypertrophic resistance training: Influence on muscle strength, size, and hormonal adaptations in trained men. *The Journal of Strength & Conditioning Research*, *19*(3), 572-582.
38. Grelsamer, R. P., Dubey, A., & Weinstein, C. H. (2005). Men and women have similar Q angles: A clinical and trigonometric evaluation. *The Journal of Bone and Joint Surgery - British Volume*, *87*(11), 1498-1501.
39. Jaiyesimi, A. O., & Jegede, O. O. (2009). Influence of gender and leg dominance on Q-angle among young adult Nigerians. *African Journal of Physiotherapy and Rehabilitation Sciences*, *1*(1), 18-23.
40. Loudon, J. K. (2016). Biomechanics and pathomechanics of the patellofemoral joint. *International Journal of Sports Physical Therapy*, *11*(6), 820.

A SURVEY ON STRUTS ARCHITECTURE FRAMEWORK

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Abstract:

This chapter proposes a procedural method for constructing a Java-based application utilizing the Struts Framework, renowned for its support in developing MVC-based web applications. The Model-View-Controller (MVC) pattern stands as a cornerstone in segregating user interface logic from business logic. Struts, being an elegant and scalable framework, caters to the creation of enterprise Java applications, aiming to streamline the entire development lifecycle—from inception to deployment and maintenance. Our research demonstrates that employing multiple frameworks to design applications utilizing MVC concepts leads to enhanced ease compared to relying solely on a single framework. Recent trends witness a surge in research papers advocating for novel, expedited approaches in implementing web architectures, often bypassing the conventional dependency on frameworks.

Introduction:

In today's landscape, the web presents a myriad of complexities. As companies and organizations strive to meet escalating demands, the intricacies and performance of web programming become paramount. The proliferation of diverse communication devices only adds to this complexity [1]. In response to the business's appetite for web-based applications across various communication channels, many companies opt for frameworks to facilitate development, recognizing the importance of robust architecture in application development [2]. Frameworks can be likened to toolkits, offering developers a suite of functions to streamline application creation. Given the escalating data load on the internet, architectural considerations become imperative. Let's delve into a brief discussion on research pertaining to the Struts2 framework. Struts, an integral component of J2EE, serves to simplify the development of enterprise-level applications. However, utilizing J2EE may necessitate designers and programmers to disperse functionality across various server-side components [3]. Initially crafted by Craig McClanahan, the Struts framework emerged from the need to address these challenges.

Literature Review:

In this section, a computer components distribution system is designed based on the architecture proposed earlier. The system incorporates various business features, including user authentication, online product catalogs, a shopping cart, special functions, order generation, checkout features, and email confirmation. To meet the system requirements, specific Servlet and JSP documents are defined, including a login page, home page, product catalog page, product details page,[4] View Cart page, and order confirmation page. The framework layout is illustrated in Figure 1.4. Adopting the MVC pattern as depicted in Figure 1.4, the business logic tier represents the Model, JSP documents serve as the View, and Servlets function as the Controller. Direct calls between JSP documents are avoided in this architecture.[5] Instead, all HTTP requests are received by the Servlet, which then invokes the appropriate business logic model. Subsequently, different JSP documents are executed based on the processing results, allowing end clients to receive HTML responses viewable in a browser.

MVC Architecture:

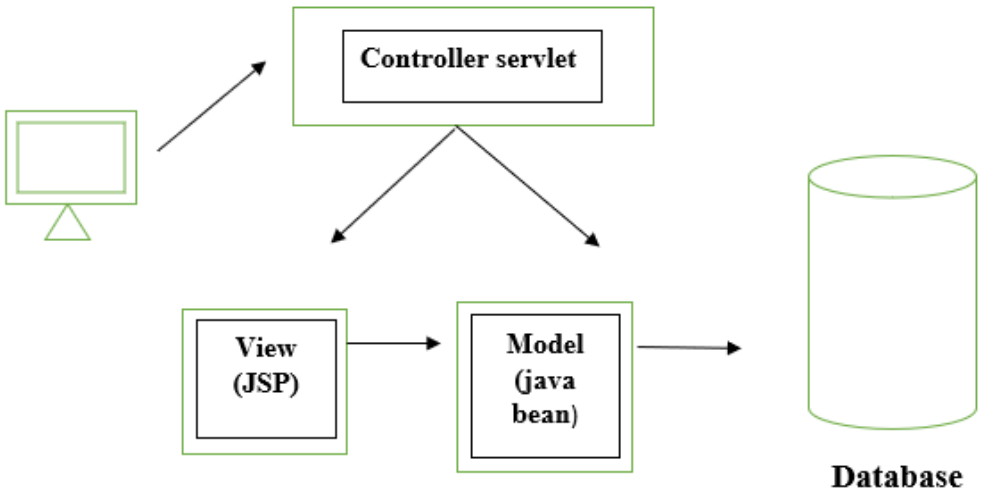

Fig. 1: MVC Architecture

The Model-View-Controller (MVC) architectural design pattern, illustrated in Figure 1, serves as a framework for interactive applications [6]. Originating from the era of Smalltalk, MVC divides an interactive application into three distinct modules, facilitating the isolation of business logic from user interface concerns. This separation allows for easier modifications to either the visual presentation or the underlying logic without impacting the other. The MVC framework comprises three interconnected components: the Model, View, and Controller, simplifying system development [7]. 1Controller: Responsible for navigation logic and interaction with the Service tier for business logic. 2. Model: Acts as

the intermediary between the Controller and the View, housing the data necessary for rendering the View. This data is populated by the Controller.3. View: Renders the response to the request and retrieves data for display [8]. In this architecture, as depicted in Figure 1, the browser initiates a request to the JSP (JavaServer Pages), which in turn accesses setter and getter methods within a Java Bean. The Bean then retrieves data from the database, and finally, the JSP sends a response back to the browser [9].

Struts Architecture:

Struts, a framework implementing a robust and adaptable controller following the Service to Worker pattern (depicted in Figure 2), offers several key advantages. These include: 1. Integration Flexibility: Struts' architecture grants flexibility in selecting the view and model components to be utilized. The view aspect is built upon the concept of plug-ins, enhancing adaptability [10]. Struts1: As an open-source framework, Struts1 extends the Java Servlet API while adhering to the Model-View-Controller (MVC) architecture. It facilitates the creation of maintainable, extensible, and versatile web applications leveraging standard technologies such as JSP pages, JavaBeans, resource bundles, and XML configurations.

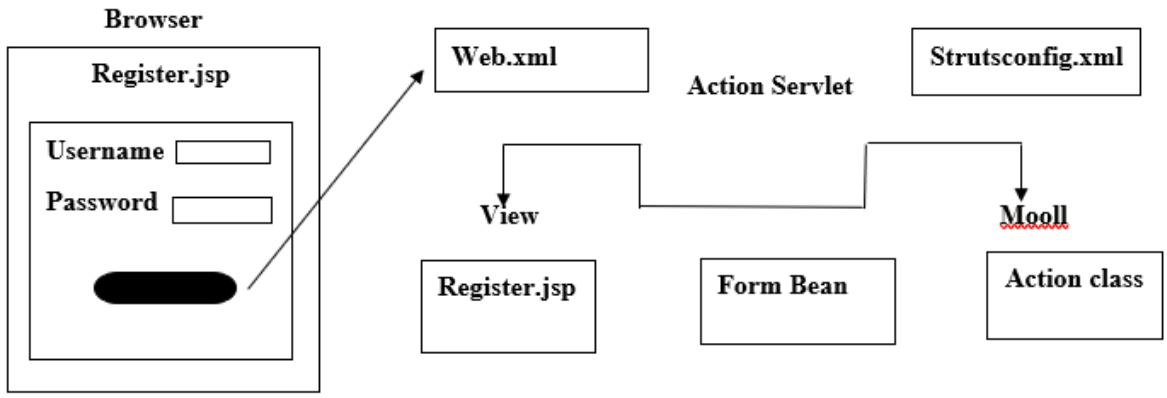

Fig. 2: Struts Framework Architecture.

Conclusion:

This paper proposes a solution to address data expression challenges, leveraging the development architecture framework provided by Struts. By utilizing Struts, effective protection of business data is achieved. Furthermore, the separation of business logic and data expression, as well as the organization of data into distinct layers, greatly enhances the ease of debugging and maintenance. In the evolving landscape of the web, achieving informatization is imperative for large-scale enterprises. Struts places significant emphasis on controlling business logic, offering a pathway to explore new scopes and business

opportunities for both companies and programmers alike. Therefore, adopting this framework is recommended for improved performance and streamlined development processes.

References:

1. Garg, R., Sood, Y., Kottana, B., et al. (2011). A framework-based approach for the development of web-based applications. *World Computer Science and Information Technology Journal (WCSIT)*, *1*(1), 1-4.
2. Wang, Y., Guo, C., & Song, L. (2009). Architecture of e-commerce systems based on J2EE and MVC pattern. *International Conference on Management of e-Commerce and e-Government*, IEEE Computer Society.
3. Gupta, P., & Govil, M. (2010). MVC design pattern for the multi-framework distributed applications using XML, Spring, and Struts framework. *International Journal of Computer Science and Engineering*, *2*(4), 1047-1051.
4. Wang, J., & Liu, F. (2002). JSP programming guide (pp. 78–94). Electronics Industry Publishing Press.
5. Xiaoshuan, Z., Peijun, C., & Ming, Z. (2008). Research on data expression in J2EE architecture system. *7th WSEAS International Conference on Applied Computer & Applied Computational Science (ACACOS '08)*, Hangzhou, China, April 6-8.
6. Bawiskar, A., Sawant, P., Kankate, V., et al. (2012). Integration of Struts, Spring, and Hibernate for an university management system. *International Journal of Emerging Technologies and Advanced Engineering*, *2*(6), 203-210.
7. Wojciechowski, J., Sakowicz, B., Dura, K., et al. (2004). MVC model, Struts framework, and file upload issues in web applications based on J2EE platform. *TCSET*.
8. Dey, T. (2011). A comparative analysis on modeling and implementing with MVC architecture. *International Conference on Web Services Computing (ICWSC)*. Proceedings published by *International Journal of Computer Applications (IJCA)*, 44-49.
9. Gupta, P., & Govil, M. (2010). Spring web MVC framework for rapid open source J2EE application development: A case study. *International Journal of Engineering Science and Technology*, *2*(6), 1684-1689.
10. Saxean, A. (2012). *Java Server Pages* (1st ed., pp. 1-447). MJP, Chennai, Tamil Nadu, India.

A COMPREHENSIVE REVIEW ON THE DESIGN, SYNTHESIS, AND APPLICATIONS OF CARBENE SUPERBASES

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Abstract:

Organic superbases represent a unique and increasingly valuable class of Brønsted bases, distinguished by their complementary properties compared to traditional inorganic bases. This review highlights the design and synthesis of divalent (II) carbenesin contemporary synthetic methodologies. Particular emphasis is placed on their benefits in three key areas: facilitating the discovery of novel base-catalyzed reactions, improving the efficiency of reactions reliant on stoichiometric Brønsted bases, and enhancing high-throughput experimentation technologies.

Keywords: Organic Superbases; Brønsted Base; Inorganic Bases; Proton Affinity.

Introduction:

In the gas phase, the threshold of superbasicity was established (DMAN, GB = 237.8 kcal mol^{-1}; bases with higher GB values are termed superbases). Nevertheless, there is no universally agreed-upon definition of superbases in solution [1,2]. For a while, the term "superbase" was used specifically for metal-organic compounds that create weakly solvated and coordinated, sometimes "naked," anions with the highest basicity in solution. The design and synthesis of neutral organic superbases have garnered significant attention since Alder's groundbreaking research on the first proton sponge, 1,8-bis(dimethylamino)naphthalene (DMAN). Numerous organic superbases have been developed using amines, imines, guanidines, phosphazenes, and quinomines as foundational building blocks [3-19]. The remarkable basicity of these compounds is achieved through various strategies, including strong lone-pair repulsion within the molecules, release of lone-pair repulsion upon protonation, robust intramolecular hydrogen bonding in the conjugate acids, and additional noncovalent interactions [9-13]. To further enhance basicity, highly functionalized amines, imines, and have been introduced. Many of these superbases are designed with a rigid molecular framework, positioning two or more basic centers in close proximity to maximize basic strength [8,9].

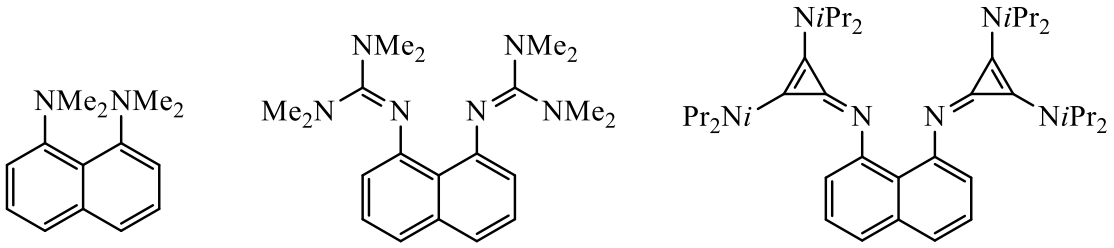
It's no surprise that organic superbases are preferred over their inorganic counterparts due to their unique advantages. They exhibit high solubility in organic solvents, low sensitivity to moisture and CO_2, and excellent stability at low temperatures, enabling mild reaction conditions [9,10]. These characteristics make organic superbases highly applicable in various fields such as asymmetric catalysis, natural product synthesis, catalytic polymerization, transition metal ligation, and CO_2/H_2 activation [20]. Different kinds of organic superbases, including compounds with amines, imines, guanidines, phosphazenes, or quinoimines, have been synthesized (Figure 1) [21]. As Schwesinger's phosphazene bases gained prominence, it became evident that a homologation strategy to enhance basicity is effective, which was later confirmed in cases of amidines and guanidines as well. Among the bases discussed, Verkade's phosphatranes stand out for having the basicity centre located on the phosphorus atom. These compounds achieve their exceptional basicity through various strategies, such as intense lone-pair repulsion, alleviation of lone-pair repulsion in the protonated form, robust intramolecular hydrogen bonding in the resulting conjugate acids, or noncovalent interactions [22]. All organic superbases typically feature two basic centers in the molecule, usually nitrogen atoms, oriented in a manner that facilitates the formation of a robust intramolecular hydrogen bond with the incoming proton.

1. Classical metalorganic superbases

(i) Unimetal superbases $\quad \mathbf{M}\text{-}CR^1_3 + \mathbf{M}\text{-}XR^2 \longrightarrow \mathbf{M}(R_3CMXR)$

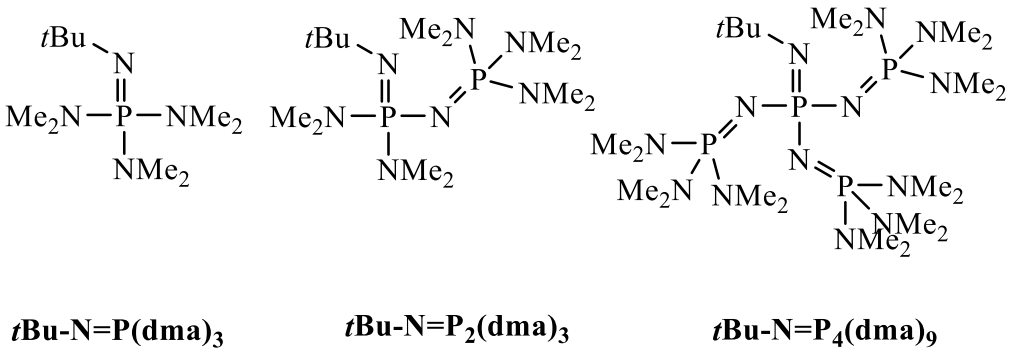
(ii) Multimetal superbases $\quad \mathbf{M^1}\text{-}CR^1_3 + \mathbf{M^2}\text{-}XR^2 \longrightarrow \mathbf{M^1}(R_3C\mathbf{M^2}XR)$

2) Proton sponges including mixed scaffold members



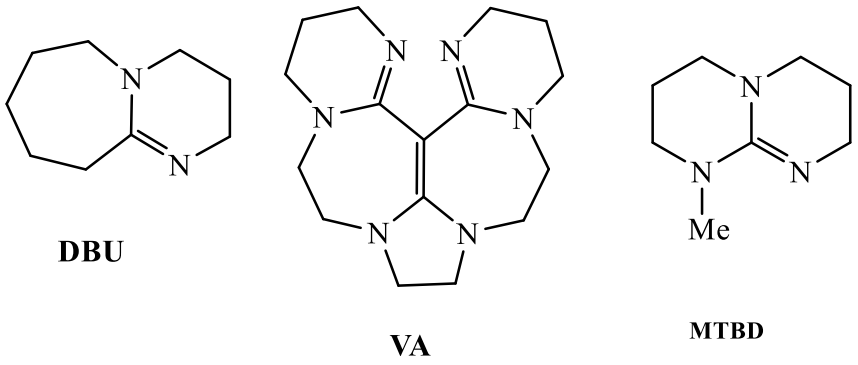
DMAN **TMGN** **DCAN**

3) Phosphazene sponges including mixed scaffold members



***t*Bu-N=P(dma)$_3$** ***t*Bu-N=P$_2$(dma)$_3$** ***t*Bu-N=P$_4$(dma)$_9$**

4) Amidine and guanidine superbases



DBU **VA** **MTBD**

Fig. 1: Various classes of nitrogen superbases

Determining the Basicity of Organic Superbases

As per the Brønsted–Lowry definition, bases are substances capable of proton acceptance. Brønsted basicity comes in two forms: gas-phase and solution-phase basicity. While solution-phase basicity is more pertinent for practical applications like organic synthesis, gas-phase basicity offers insights into the inherent properties of bases.

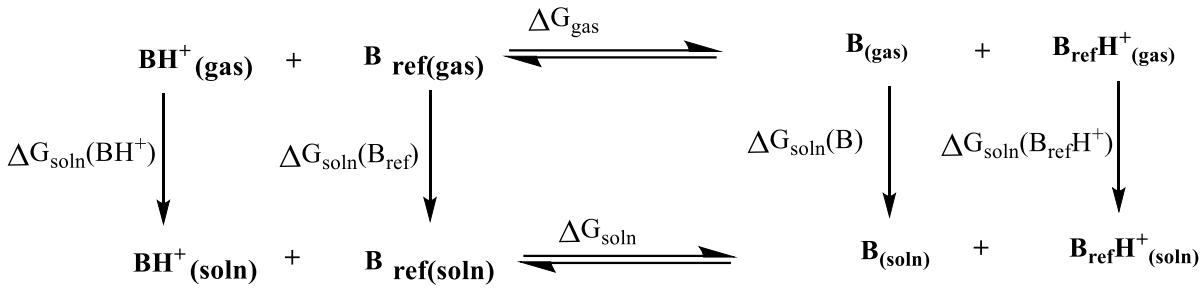
Gas-Phase Basicity

Proton affinity (PA) and gas-phase basicity (GB) are measures that describe a molecule's inherent ability to accept a proton. Proton affinity refers to the negative enthalpy change under standard conditions, namely temperature and pressure, for a gas-phase reaction [23].

$B + H^+ \leftrightarrow \Delta H_b$, $\Delta G_b BH^+$ $PA \equiv -\Delta H_b$, $GB \equiv -\Delta G_b$ (1)

In contrast, gas-phase basicity refers to the negative free-energy value associated with this reaction (eq 1).

Scheme 1. Thermodynamic cycle used for pK_a computation



Gas-phase basicity (GB) values are usually determined using the equilibrium constant (K) for proton transfer between two bases, B_1 and B_2, as described by equation 2:

$B_1H^+ + B_2 \leftrightarrow KB_1 + B_2H^+$, $\Delta GB = -RT \ln K$ (2)

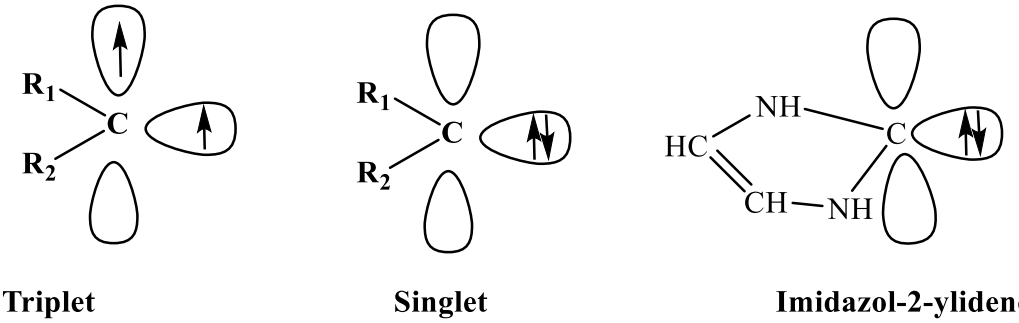
Calculating gas-phase basicity (GB) from ΔGB is simple if the GB of one of the bases (reference base) is already established. Proton affinity (PA) is typically derived from GB by incorporating the entropy term, which is estimated separately, as shown in equation 3:

$PA = GB + T\Delta S$ (3)

Computational methods such as ab initio and density functional theory (DFT) are capable of providing reliable estimates for proton affinity (PA) and gas-phase basicity (GB), which can sometimes be challenging to determine experimentally. The precision of calculated PA and GB values relies on the chosen level of theory. For highly accurate results, ab initio methods employing coupled cluster theory, specifically CCSD(T), in conjunction with extensive basis sets are preferred. Even greater precision in computing thermochemical data, with deviations as low as 0.25 kcal mol^{-1} from experimental values, can be attained by employing composite methods like the Weizmann-n ab initio approach. Both the CC and W_n methods are highly computationally demanding and are limited to small molecules. Organic superbases typically comprise tens to hundreds of atoms, necessitating a balance between accuracy and computational feasibility when calculating their PA and GB values. DFT methods provide a satisfactory compromise between computational accuracy and efficiency, making them commonly employed in PA and GB calculations. Bachrach evaluated the performance of three commonly used DFT functionals—B3LYP, WB97XD, and M062X—using the 6-311+G(2d,p) basis set. This evaluation was based on experimental data for the proton affinity of 44 nitrogen bases. Overall, all three DFT functionals demonstrated reasonably good performance, with absolute mean differences from experimental values of 1.10, 1.22, and 3.29 kcal mol^{-1}, respectively.

Basicity and Superbasicity of Carbene:

Carbenes are commonly understood as neutral compounds containing a carbon atom with two covalent bonds and a lone pair, making the carbon divalent with six valence electrons [24]. In the triplet state ($\sigma^1P_\pi^1$), the nonbonding electrons occupy separate orbitals with parallel spins, while in the singlet state, these electrons have opposite spins and may reside in the same σ or P_π orbital (Figure 2). The parent carbene (H_2C:) has a triplet ground state and is stable only in the interstellar medium. However, amino and phosphino carbenes possess a singlet ground state, allowing them to be isolated under standard laboratory conditions [25,26]. A singlet carbene contains one lone pair of electrons and an empty p-orbital, allowing it to function as both a σ-donor and a π-acceptor ligand. Therefore, singlet, spin-paired carbenes can readily accept a proton or other electrophile, forming a carbocation as the conjugate acid.Singlet carbenes have indeed been utilized as ligands in transition metal catalysis.



Triplet **Singlet** **Imidazol-2-ylidene singlet**

Fig. 2: Singlet and triplet carbene

In terms of reactivity and applications, stable singlet carbenes function as classical single-site ambiphiles, with both donor and acceptor orbitals located at the carbene center [27]. In addition to various amines and imines, divalent carbon(II) compounds also exhibit high proton affinity.

Earlier studies have focused on a limited number of simple carbenes, such as difluorocarbene ($:CF_2$, 172 ± 2 kcal/mol) and dichlorocarbene ($:CCl_2$, 208.3 ± 2 kcal/mol), along with related compounds like silylene ($:SiH_2$, 201 ± 3 kcal/mol) [28]. These values were determined using proton transfer bracketing methods. A major breakthrough in carbene chemistry is the successful isolation of a stable singlet N-heterocyclic carbene, 1,3-di-1-adamantylimidazol-2-ylidene (where R = 1-adamantyl), achieved simply through the deprotonation of an imidazolium salt (Figure 3a) [29]. N-heterocyclic carbenes (NHCs) function both as ligands for organometallic catalysts and as standalone catalysts. They are most notably employed as nucleophilic species in Umpolung chemistry but also play a role

as Brønsted bases in various organic reactions. Despite the significance of N-heterocyclic carbenes (NHCs) in catalysis, studies and measurements of their properties remain surprisingly limited. A deeper understanding of these species is essential for uncovering catalytic mechanisms and developing more efficient catalysts.

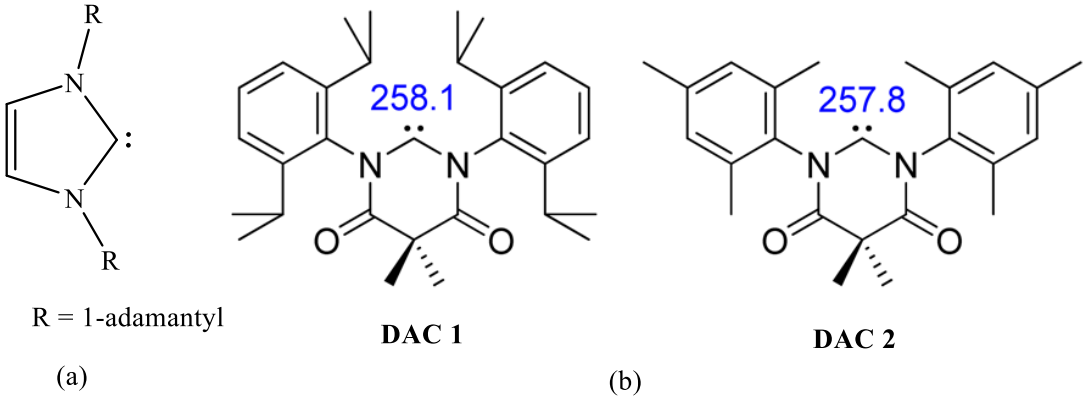


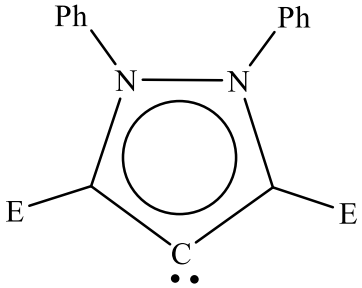
Fig. 3: The synthesized carbene superbases

Since the successful isolation of imidazol-2-ylidene carbene, numerous carbenes stable at room temperature have been synthesized. Initially the synthesis and proton affinity of N-Heterocyclic carbenes (NHCs) (neutral species containing a carbene carbon and at leastone adjacent nitrogen atom within a ring structure) were studied extensively. The experimentally determined proton affinity of 1-ethyl-3-methyl-imidazol-2-ylidene is 251.3 ± 4 kcal/mol, placing it within the superbase range [29].These measurements represent the first experimental determination of gas-phase proton affinities (PAs) for N-heterocyclic carbene superbases.The authors examined the gas-phase proton affinities (PAs) of N-heterocyclic carbenes, using an extended version of the kinetic method.Furthermore, density functional theory (DFT) calculations at the B3LYP/6-31+G(d) level was performed, revealing that the calculated value exceeds the experimental value by 9.5 kcal/mol.The findings suggest that carbenes, with minimal functionalization compared to amines, imines, and phosphazenes, are promising candidates as ultra-strong organic superbases. Furthermore, various researcher

Lee and co-workers investigated the gas-phase proton affinities (PAs) of a series of novel diamidocarbenes (DACs) using both experimental and computational methods. They compared these results to the proton affinities of various imidazolylidene-based N-heterocyclic carbenes (NHCs) [30]. In this study, they initially calculated the proton affinities (PAs) of the known diamidocarbenes (DACs) 1 and 2 using density functional

theory, finding a PA of 258 kcal/mol. The calculated PA values for N-heterocyclic carbenes (NHCs) 3a–d were only slightly higher (260–266 kcal/mol) than DACs, shown in Figure 3b.

Bertrand and co-workers reported pyrazol-4-ylidenes, a highly basic type of carbene [31]. These mesoionic carbenes, also known as cyclic-bentallenes (CBA), exhibit basicity surpassing that of Verkade's proazaphosphatrane and even Schwesinger's phosphazene $P_4(^t\text{Bu})$. In this study they have examined electronicproperties of fifteen structurally diverse populartypes of carbenes. They found that, among the examined dyes, CBA was the most basic carbene. Neither the iso-butyl Verkade base nor the phosphonium ylides A could deprotonate the conjugate acid of CBA (figure 4). Furthermore, they focused on N-CBA, a cyclic-bentallene featuring two exocyclic π-donor pyrrolidinyl substituents, which are less electronegative than the aryloxy groups present in CBA.It is found that N-CBA is more basic than the Schwesinger $P_4(^t\text{Bu})$ superbase. Remarkably, replacing the aryloxy groups of CBA ($p\text{K}_{\text{aH}}$< 37.7) with amino groups in N-CBA significantly increases the pK_{aH} by several orders of magnitude, exceeding 42.7.



E = Oxyl
E = $N(CH_2)_4$

Cyclic-bentallenes (**CBA**)

Fig. 4: Neutral superbases

Various computational studies have been conducted to explore carbene superbases and their applications. Ganguly and co-workers designed a molecular framework comprising an acyclic carbene [**:**$C(NRR')_2$] unit attached to a phenyl ring with alkyl chains (Figure 5) [32]. This framework achieved a proton affinity value of approximately 300.0 kcal mol^{-1}, comparable to the calculated PAs of highly basic phosphazenes. In these systems, high basicities are typically attained by connecting multiple phosphazene units through covalent bonds. Here, the [**:**$C(NRR')_2$] unit is anchored to the phenyl ring, achieving enhanced basicity through C–H···π interactions. These interactions contributed up to ~25.0 kcal mol^{-1}, significantly increasing the basicity of the phenyl-anchored [**:**$C(NRR')_2$] compared to the standalone acyclic carbene [**:**$C(NRR')_2$].

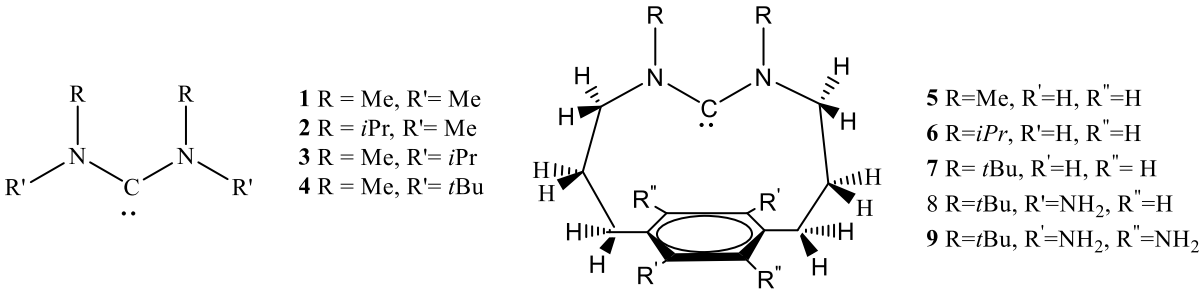
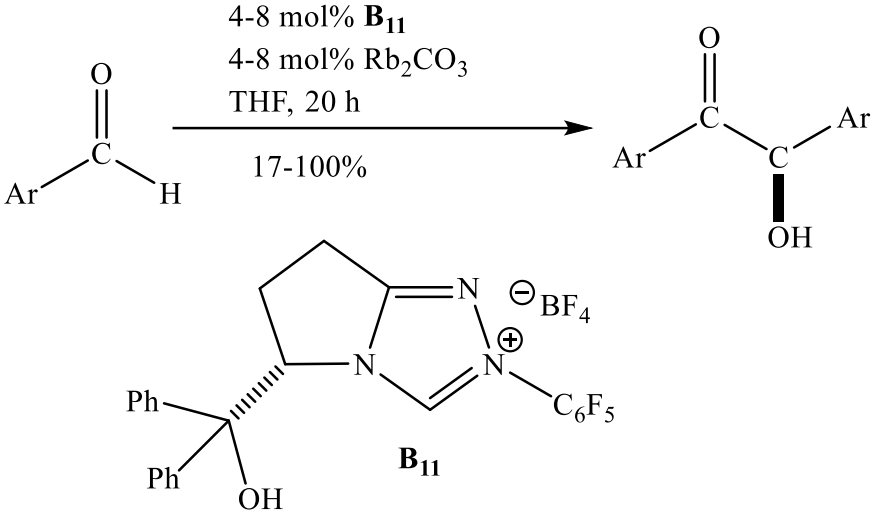


Fig. 5: The designed carbene superbases

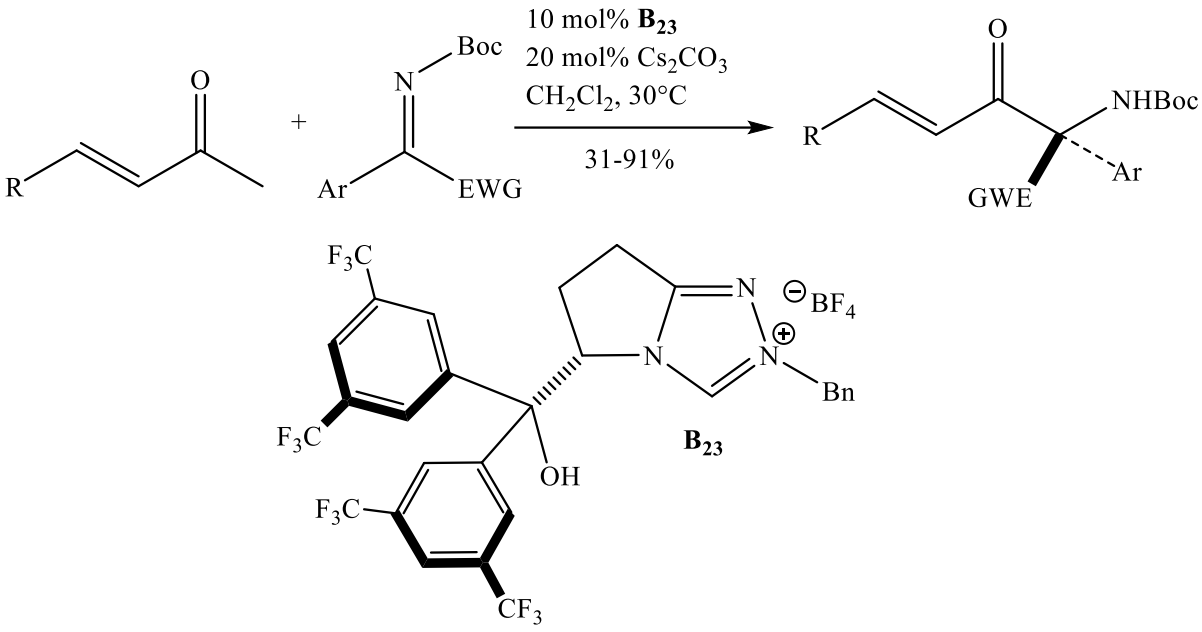
Application of Carbene Superbases:

The benzoin reaction is one of the most extensively studied transformations using NHC catalysts. Connon, Zeitler, and their colleagues have established the most effective conditions reported so far for the enantioselective benzoin reaction [33]. With just 4 mol% of the triazolium precatalyst B_{11}, they achieved the homocoupling of benzaldehyde in 90% yield and >99% enantiomeric excess (ee) (Scheme 1). The remarkable catalytic efficiency of B_{11} is attributed to the presence of an H-bonding group, which plays a critical role in controlling selectivity. Additionally, various other aryl aldehydes can also undergo this reaction with high stereocontrol, though the results are less consistent.



Scheme 1: Highly Efficient Catalytic System for the Enantioselective Benzoin Reaction

Enders and colleagues were the first to report the cross-aza-benzoin reaction between furfural derivatives and trifluoromethyl ketimines, obtaining moderate to good yields (32–87%) with the use of an achiral triazolium precatalyst [34]. Similarly, Ye and co-workers showcased the coupling of enals with trifluoromethyl ketones, achieving excellent enantioselectivity through the use of the chiral triazolium catalyst **B_{23}**. Interestingly, these conditions were also compatible with other electron-withdrawing groups on the imine (Scheme 2) [35].



Scheme 2: Cross-Aza-Benzoin Reaction with Ketimines

Ganguly and co-workers demonstrated that carbene superbases are highly effective for CO_2 capture in the presence of alcohols, leading to the formation of propylcarbonate salts [36]. This pathway is energetically more favorable than direct CO_2 capture by these carbenes. By fine-tuning the steric and electronic properties of these carbenes, the mode of CO_2 capture can be modulated. Notably, both acyclic and N-heterocyclic carbenes (NHCs) are predicted to have higher pKa values than commonly used superbases such as DBU, TBD, and DBN. These superior properties make them promising candidates for practical applications in carbon capture and sequestration (CCS). In another study, paracyclophane-based carbene systems were reported and utilized for the selective binding of lithium ions by Ganguly et. al. [37]. These lithium-decorated systems can serve as molecular containers for storing multiple dihydrogen molecules. This represents the first example of using lithiated organic superbases as hydrogen storage materials. Conceptual density functional theory (DFT) calculations of reactivity descriptors, such as electronegativity, hardness, and electrophilicity, confirmed the stability of these H_2-trapped molecules. Additionally, the calculated desorption energies per H_2 molecule (ΔE_{DE}) highlight the recyclable nature of these hydrogen storage materials.

Conclusion:

This review highlights the diverse chemistry of carbene superbases and their significant impact on organic and material chemistry. These compounds have frequently

enabled the mild and efficient synthesis of complex molecules from simple starting materials.

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Reference:

1. Alder *et al.* (1989): Strain Effects on Amine Basicities, Chem. Rev. 89, 1215–1223.
2. Alder *et al.* (1968): The Remarkable Basicity of 1,8-Bis(dimethylamino)naphthalene, Chem. Commun. 723–724.
3. Raczyńska *et al.* (1994): Superbases in the Gas Phase. Part II. Further Extension of the Basicity Scale Using Acyclic and Cyclic Guanidines. J. Phys. Org. Chem. 7, 725–733.
4. Howard *et al.* (2002): Relationships Between Basicity, Structure, Chemical Shift and the Charge Distribution in Resonance-Stabilized Iminoamines. J. Chem. Soc., Perkin Trans. 2, 899–905.
5. Bachrach *et al.* (2010): Using the Pyridine and Quinuclidine Scaffolds for Superbases: A DFT Study. J. Org. Chem., 75, 2651–2660.
6. Maksić *et al.* (1999): Spatial and Electronic Structure of Highly Basic Organic Molecules: Cyclopropeneimines and Some Related Systems. J. Phys. Chem. A, 103, 6678–6684.
7. Singh *et al.* (2006): C2-Chiral Substituted cis-1,3,5,7-Tetraazadecalins as Proton Sponges: A Computational Study. Eur. J. Org. Chem., 4938–4942.
8. Singh *et al.* (2007): DFT Studies toward the Design and Discovery of a Versatile Cage-Functionalized Proton Sponge. Eur. J. Org. Chem., 420–422.
9. Singh *et al.* (2007): Rational Design and First-Principles Studies toward the Remote Substituent Effects on a Novel Tetracyclic Proton Sponge. J. Phys. Chem. A, 111, 6468–6471.
10. Singh *et al.* (2008): Strategic Design of Small and Versatile Bicyclic Organic Superbases: A Density Functional Study. New. J. Chem. 32, 210–213.

11. Maksić *et al.* (2000): Absolute Proton Affinity of Some Polyguanides. J. Org. Chem. 65, 3303−3309.
12. Vianello *et al.* (2002): In Search of Neutral Organic Superbases-Iminopolyenes and Their Amino Derivatives. New. J. Chem. 26, 1324−1328.
13. Kovačević *et al.* (2002): The Proton Affinity of the Superbase 1,8-Bis(tetramethylguanidino)-naphthalene (TMGN) and Some Related Compounds: A Theoretical Study. Chem. −Eur. J. 8, 1694−1702.
14. Margetic *et al.* (2010): Exceptional Superbasicity of Bis(guanidine) Proton Sponges Imposed by the Bis(secododecahedrane) Molecular Scaffold: A Computational Study. Eur. J. Org. Chem. 6563−6572.
15. Coles *et al.* (2009): Superbasicity of a Bis-guanidino Compound with a Flexible Linker: A Theoretical and Experimental Study. J. Am. Chem. Soc. 131, 16858−16868.
16. Peran *et al.* (2011): Polycyclic Croissant-Like Organic Compounds are Powerful Superbases in the Gas Phase and Acetonitrile-A DFT Study. Chem. Commun. 47,1327−1329.
17. Koppel *et al.* (2001): Intrinsic Basicities of Phosphorus Imines and Ylides: A Theoretical Study. J. Phys. Chem. A 105, 9575−9586.
18. Lo *et al.* (2011): Exploiting Propane-1,3-Diimines as Building Blocks for Superbases: A DFT Study. New J. Chem. 35, 2544−2550.
19. Schwesinger *et al.* (1996): Extremely Strong, Uncharged Auxiliary Bases; Monomeric and Polymer-Supported Polyaminophosphazenes (P2- P5). Liebigs Ann. 1055−1081.
20. Puleo *et al.* (2021): Organic Superbases in Recent Synthetic Methodology Research, Chem. −Eur. J. 27, 4216-4229.
21. Vazdar *et al.* (2021): Design of Novel Uncharged Organic Superbases: Merging Basicity and Functionality, Acc. Chem. Res. 54, 3108−3123.
22. Chatelet *et al.* (2013): Superbases in Confined Space: Control of the Basicity and Reactivity of the Proton Transfer, J. Am. Chem. Soc., 135, 18659−18664.
23. Biswas *et al.* (2013): Is the Isodesmic Reaction Approach a Better Model for Accurate Calculation of pK_a of Organic Superbases? A Computational Study Synlett, 24, 2519-2524.
24. Biswas *et al.* (2013): First Principles Studies toward the Design of Silylene Superbases: A Density Functional Theory Study J. Phys. Chem. A 117, 3109−3117.
25. Bourissou *et al.* (2000): Stable Carbenes, Chem. Rev. 100, 39−91.

26. Kascatan-Nebioglu *et al.* (1991): Synthesis and Structural Characterization of N-Heterocyclic Carbene Complexes of Silver(I) and Rhodium(I) from Caffeine. J. Am. Chem. Soc. 113, 361−363.
27. Despagnet-Ayoub *et al.* (2004): A Stable Four-Membered N-Heterocyclic Carbene, J. Am. Chem. Soc. 126, 10198–10199.
28. Bellotti *et al.* (2021): Recent advances in the chemistry and applications of N-heterocyclic carbenes, Nat Rev Chem. 5, 711-725.
29. Chen *et al.* (2005): Proton Affinities of N-Heterocyclic Carbene Super Bases, Org. Lett. 7, 18, 3949–3952.
30. Chen *et al.* (2013): Assessing the Proton Affinities of N,N′-Diamidocarbenes, J. Org. Chem. 78, 10452–10458.
31. Vermersch *et al.* (2021): Stable Singlet Carbenes as Organic Superbases, Angew. Chem. Int. Ed. 60, 27253 –27257.
32. Lo *et al.* (2011): First principle studies toward the design of a new class of carbene superbases involving intramolecular H⋯ π interactions, Chemical Communications 47 (26), 7395-7397.
33. Baragwanath *et al.* (2009): Highly Enantioselective Benzoin Condensation Reactions Involving a Bifunctional Protic Pentafluorophenyl-Substituted Triazolium Precatalyst. J. Org. Chem.74, 9214−9217.
34. Enders *et al.* (2009): N-Heterocyclic Carbene Catalyzed Nucleophilic Acylation of Trifluoromethyl Ketimines. Synthesis 4125−4128.
35. Sun *et al.* (2013): Enantioselective NHeterocyclic Carbene Catalyzed Aza-benzoin Reaction of Enals with Activated Ketimines. Angew. Chem., Int. Ed. 52, 5803−5806.
36. Lo *et al.* (2012): Efficacy of carbenes for CO_2 chemical fixation and activation by their superbasicity/alcohol: a DFT study, New J. Chem., 36, 2549–2554.
37. Lo *et al.* (2013): In Silico Studies in Exploiting Weak Noncovalent C−H^+⋯π and π−π Interactions To Achieve Dual Properties: Hyperbasicity and Multiple Dihydrogen Storage Materials with Paracyclophane-Based Carbene Derivatives, The Journal of Physical Chemistry C 117, 19325-19333.

TRANSFORMING DRUG DISCOVERY: A PATIENT-CENTERED PARADIGM

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Abstract:

This chapter explores the essential role of health and patient welfare in pharmaceutical product development, emphasizing the integration of patient-centered approaches, safety, efficacy, and equitable access to medications. It highlights the importance of aligning drug development efforts with the needs and preferences of diverse patient populations to ensure that medical innovations meaningfully address real-world challenges. Patient-centered strategies are pivotal in this process, recognizing patients as active participants rather than passive recipients of care. By incorporating patient insights into research and development, pharmaceutical companies can design therapies that are more effective, accessible, and aligned with patients' lived experiences. Equally important are rigorous safety and efficacy standards, which ensure that medications meet the highest benchmarks for minimizing risks while delivering meaningful health benefits. The chapter also examines equitable access to medications, advocating for strategies to bridge gaps in healthcare availability, particularly in underserved populations. It underscores the need to dismantle barriers such as affordability, regulatory hurdles, and systemic inequities to promote global health equity. Additionally, the chapter explores ethical and regulatory considerations, emphasizing the responsibility of pharmaceutical companies to maintain transparency, accountability, and respect for patients' rights throughout the drug development process. It calls for collaboration among key stakeholders, including healthcare providers, regulators, policymakers, and patient advocacy groups, to advance innovation while safeguarding public health and fostering trust. By prioritizing patient engagement, upholding ethical standards, and championing accessibility, the pharmaceutical industry can drive meaningful medical advancements that improve individual and community health outcomes. This chapter envisions a future where pharmaceutical innovation is rooted in empathy, collaboration, and equity, ensuring that the benefits of scientific progress reach all, regardless of geographic, social, or economic barriers.

Keywords: Health And Patient Welfare, Pharmaceutical Product Development, Patient-Centered Approaches, Global Health Equity, Ethical Considerations, Regulatory Frameworks, Transparency, Accountability, Stakeholder Collaboration, Medical Innovation, Affordability Barriers, Systemic Inequities, Public Health, Empathy, Collaboration.

Introduction:

The landscape of pharmaceutical product development is continually evolving, driven by advancements in scientific research, technological innovation, and shifting healthcare needs. At the heart of this dynamic process lies a fundamental commitment to health and patient welfare. This introduction sets the stage for exploring the multifaceted considerations that underpin pharmaceutical product development, with a particular focus on the pivotal role of health and patient welfare.[1]

Pharmaceutical companies operate within a complex ecosystem, where scientific discovery intersects with regulatory oversight, market dynamics, and societal expectations. Against this backdrop, the pursuit of medical innovation must be balanced with ethical imperatives, ensuring that the products brought to market not only alleviate suffering and improve patient outcomes but also uphold principles of safety, efficacy, and accessibility.

Central to the ethos of pharmaceutical product development is the concept of patient-centered care. Recognizing that patients are not merely recipients of medical interventions but active participants in their own health journey, pharmaceutical companies are increasingly embracing approaches that prioritize patient engagement, empowerment, and advocacy. By soliciting patient insights, incorporating patient-reported outcomes, and fostering collaborative partnerships, drug developers can better understand the lived experiences and treatment preferences of diverse patient populations, thereby informing more tailored and impactful therapeutic interventions.

Moreover, the quest for medical innovation is intrinsically linked to the pursuit of safety and efficacy. Rigorous preclinical and clinical testing protocols, guided by ethical principles and regulatory standards, serve as essential safeguards to protect patient well-being and public health. Through meticulous risk assessment, pharmacovigilance, and post-market surveillance, pharmaceutical companies strive to identify and mitigate potential risks associated with investigational drugs, ensuring that the benefits of therapy outweigh the potential harms.

Equitable access to essential medications represents another cornerstone of pharmaceutical product development. In an era marked by widening health disparities and inequitable distribution of resources, addressing barriers to access is imperative for promoting health equity and social justice. By adopting access-oriented strategies, such as differential pricing, licensing agreements, and philanthropic initiatives, pharmaceutical companies can expand access to life-saving therapies in underserved communities, thereby advancing the global health agenda.

As we navigate the complexities of pharmaceutical product development, it is essential to remain steadfast in our commitment to health and patient welfare. By embracing patient-centered care, upholding standards of safety and efficacy, and championing equitable access to medications, the pharmaceutical industry can fulfill its mission of improving human health and advancing the collective well-being of society.

In the chapters that follow, we will delve deeper into the various dimensions of health and patient welfare in pharmaceutical product development, exploring ethical considerations, regulatory frameworks, access strategies, and the transformative potential of patient-centered approaches. Through this exploration, we aim to illuminate the pathways toward a more compassionate, equitable and sustainable future for pharmaceutical innovation.

Health and patient welfare stand at the forefront of pharmaceutical product development, guiding the research, design, and implementation of innovative therapies aimed at improving patient outcomes and quality of life. This chapter explores the pivotal role of health and patient welfare in shaping pharmaceutical product development strategies, with a focus on fostering patient-centered approaches, ensuring safety and efficacy, and promoting equitable access to essential medications.[2]

Introduction to health and patient welfare in pharmaceutical product development

Pharmaceutical product development represents a dynamic intersection of scientific innovation, regulatory scrutiny, and societal need, with the overarching goal of improving patient health outcomes. At the heart of this endeavor lies a profound commitment to health and patient welfare, guiding every stage of the drug development process from initial research to market access and beyond. The significance of health and patient welfare in pharmaceutical product development cannot be overstated. While scientific breakthroughs drive the discovery of new therapies, it is the impact on patient lives that truly measures success. Therefore, this introduction serves as a foundational exploration into the multifaceted considerations surrounding health and patient welfare

within the context of pharmaceutical innovation.[3]

Patient-centered care

Central to the ethos of pharmaceutical product development is the principle of patient-centered care. This approach recognizes patients as active participants in their healthcare journey, emphasizing their unique perspectives, preferences, and experiences. By integrating patient insights into research, development, and delivery processes, pharmaceutical companies can ensure that therapies are not only effective but also aligned with the diverse needs and values of individuals.[4]

Safety and efficacy

Upholding standards of safety and efficacy is paramount in pharmaceutical product development. Before a new drug reaches the market, it undergoes rigorous testing through preclinical studies and clinical trials to assess its safety profile, pharmacological activity, and therapeutic efficacy. Regulatory agencies, such as the FDA in the United States and the EMA in Europe, play a critical role in evaluating the scientific evidence and determining whether a drug meets the necessary criteria for approval.

Ethical considerations

Ethical principles serve as guiding lights throughout the drug development process, ensuring that research is conducted with integrity, respect, and beneficence. From obtaining informed consent from study participants to safeguarding vulnerable populations and upholding data privacy, ethical considerations permeate every aspect of pharmaceutical research and development. Transparency, honesty, and accountability are essential virtues that underpin ethical conduct in pursuit of patient welfare.

Access and affordability

Equitable access to medications is a fundamental component of healthcare justice. However, disparities in access persist, particularly in low- and middle-income countries where financial constraints and structural barriers impede patients' ability to obtain essential treatments. Pharmaceutical companies are increasingly exploring innovative access strategies, such as differential pricing, voluntary licensing, and humanitarian initiatives, to expand access to medications and address unmet medical needs on a global scale.

Patient-centered drug discovery and development

In the landscape of pharmaceutical innovation, the paradigm of patient- centered drug discovery and development represents a transformative approach that places patients at the forefront of decision-making processes. This chapter delves into the

principles, methods, and benefits of patient- centered drug discovery and development, highlighting its profound implications for improving healthcare outcomes and fostering a culture of empathy, collaboration, and innovation within the pharmaceutical industry.[5]

Understanding patient-centered care

Patient-centered care embodies a holistic approach that acknowledges patients as individuals with unique preferences, values, and experiences. In the context of drug discovery and development, this entails actively engaging patients as partners throughout the research process, from the identification of unmet medical needs to the design of clinical trials and beyond. By soliciting patient insights, concerns, and priorities, pharmaceutical companies can gain a deeper understanding of disease burden, treatment expectations, and real- world challenges faced by patients, thereby informing more targeted and meaningful therapeutic interventions.[6]

Methods of patient engagement

Various methods of patient engagement can be employed to integrate patient perspectives into drug discovery and development activities. These may include patient advisory boards, focus groups, surveys, interviews, and participatory design sessions, among others. By leveraging these channels of communication, pharmaceutical companies can establish collaborative partnerships with patients and caregivers, fostering a sense of ownership and empowerment in the research process. Moreover, digital technologies and social media platforms offer novel opportunities for patient engagement, enabling real-time feedback, data sharing, and community-building initiatives that amplify patient voices and drive co-creation of healthcare solutions.

Benefits of patient-centered approaches

Embracing patient-centered approaches yields numerous benefits for both patients and pharmaceutical stakeholders. For patients, it enhances treatment satisfaction, adherence, and health outcomes by addressing their unique needs and preferences. By incorporating patient-reported outcomes and experiential data into clinical trial endpoints, pharmaceutical companies can capture a more comprehensive understanding of treatment efficacy and safety, ultimately leading to better-informed healthcare decision-making. From a business standpoint, patient-centered drug development fosters greater trust, loyalty, and brand reputation, positioning companies as leaders in patient- centric innovation and fostering long-term partnerships with healthcare providers, payers, and advocacy organizations.

Challenges and Considerations

Despite the inherent value of patient-centered approaches, several challenges and considerations must be addressed to realize their full potential. These may include logistical barriers to patient engagement, such as recruitment and retention challenges, as well as regulatory constraints governing the collection and utilization of patient data. Moreover, cultural and organizational barriers within pharmaceutical companies may hinder the adoption of patient-centric practices, necessitating a cultural shift towards greater empathy, flexibility, and collaboration across multidisciplinary teams.

Conclusion

Patient-centered drug discovery and development represent a paradigm shift towards more inclusive, transparent and accountable healthcare practices. By embracing patient perspectives, values and priorities, pharmaceutical companies can drive meaningful innovation, improve treatment outcomes, and enhance the overall quality of care. As we navigate the complexities of drug development in an increasingly patient-centric era, the principles of empathy, collaboration, and empowerment will continue to serve as guiding beacons, illuminating the path towards a more compassionate and equitable healthcare future.

Safety and efficacy considerations

Ensuring the safety and efficacy of pharmaceutical products is paramount in drug development, representing a fundamental commitment to patient welfare and public health. This chapter explores the rigorous processes and standards implemented to evaluate the safety and efficacy of investigational drugs, highlighting the pivotal role of preclinical and clinical research, regulatory oversight, and pharmacovigilance in safeguarding patient well- being and optimizing therapeutic outcomes.

Preclinical assessment

Preclinical studies serve as the initial phase of drug development, providing essential insights into a compound's pharmacological properties, toxicity profile, and potential therapeutic effects. In vitro experiments and animal models are utilized to assess drug activity, pharmacokinetics, and safety parameters before progressing to human testing. By conducting comprehensive preclinical evaluations, pharmaceutical companies can identify promising drug candidates while mitigating the risk of unforeseen adverse effects in subsequent clinical trials.[7]

Clinical trials

Clinical trials represent the gold standard for evaluating the safety and efficacy of

investigational drugs in human subjects. These trials are conducted in multiple phases, each designed to address specific research objectives and regulatory requirements. Phase I trials focus on safety and pharmacokinetics, phase II trials assess preliminary efficacy and dose-ranging, while phase III trials evaluate therapeutic effectiveness and safety in larger patient populations. Regulatory agencies, such as the FDA and EMA, review clinical trial data to determine whether a drug meets the necessary criteria for marketing approval, considering factors such as risk-benefit balance, study design, and patient population characteristics.

Post-market surveillance

Post-market surveillance encompasses ongoing monitoring of drug safety and efficacy following regulatory approval and commercialization. Pharmacovigilance programs systematically collect, analyze, and assess real- world data on adverse drug reactions, medication errors, and off-label use to identify potential safety concerns and inform risk management strategies. Pharmaceutical companies collaborate with regulatory authorities, healthcare providers, and patients to enhance pharmacovigilance efforts, ensuring timely detection and response to emerging safety signals.

Regulatory oversight

Regulatory agencies play a central role in evaluating the safety and efficacy of pharmaceutical products, overseeing the entire drug development lifecycle from preclinical research to post-market surveillance. These agencies establish rigorous standards and guidelines for drug approval, conduct thorough reviews of marketing applications, and enforce compliance with Good Clinical Practice (GCP) regulations to ensure the integrity and reliability of clinical trial data. By maintaining a robust regulatory framework, regulatory authorities safeguard public health while fostering innovation and access to safe and effective medications.

Challenges and emerging trends

Despite advances in drug development and regulatory science, several challenges persist in ensuring the safety and efficacy of pharmaceutical products. These may include the complexity of disease mechanisms, heterogeneity of patient populations, and limitations of existing research methodologies. Additionally, emerging trends such as personalized medicine, digital health technologies, and accelerated pathways for drug approval pose new opportunities and challenges in balancing innovation with patient safety and public health protection.

Conclusion

Safety and efficacy considerations are foundational principles that guide pharmaceutical product development, reflecting a steadfast commitment to patient welfare and healthcare quality. Through rigorous preclinical and clinical research, robust regulatory oversight and proactive pharmacovigilance efforts, stakeholders across the pharmaceutical ecosystem collaborate to deliver safe, effective, and innovative therapies that improve patient outcomes and advance public health. As we navigate the evolving landscape of drug development, the principles of patient safety, scientific rigor, and ethical integrity remain paramount, ensuring that new medications meet the highest standards of quality and benefit the individuals and communities they serve.[8]

Ethical and regulatory frameworks

Ethical and regulatory frameworks form the cornerstone of pharmaceutical product development, providing guidelines and standards to ensure the responsible conduct of research, protect human subjects, and uphold public health interests. This chapter examines the essential principles, mechanisms, and challenges inherent in navigating the complex landscape of ethical and regulatory considerations within the pharmaceutical industry.

Ethical principles in research conduct Clinical trial transparency and data sharing

Transparency and data sharing initiatives are increasingly recognized as essential components of ethical research conduct and regulatory oversight. Pharmaceutical companies are encouraged to register clinical trials, disclose study results, and share anonymized patient-level data to enhance transparency, accountability, and scientific collaboration. By promoting open access to research findings, stakeholders can foster greater trust, reproducibility, and innovation in drug development while maximizing the public health impact of research investments.

Emerging ethical and regulatory challenges

The pharmaceutical industry faces a myriad of emerging ethical and regulatory challenges, including those related to the globalization of clinical research, the use of novel technologies such as gene editing and artificial intelligence, and the tension between innovation and access in resource- constrained settings. Additionally, evolving concepts such as patient-centered research, real-world evidence, and value-based healthcare present new opportunities and dilemmas in navigating ethical and regulatory frameworks.

Conclusion

Ethical and regulatory frameworks serve as indispensable safeguards in pharmaceutical product development, guiding the responsible conduct of research, protecting human subjects, and promoting public health interests. By upholding principles of integrity, transparency, and accountability, stakeholders across the pharmaceutical ecosystem can navigate complex ethical dilemmas, mitigate risks, and advance the shared goal of delivering safe, effective, and ethically sound therapies to patients worldwide. As we confront evolving challenges and opportunities in drug development, a commitment to ethical principles and regulatory compliance remains paramount, ensuring that innovation serves the common good and upholds the dignity and well-being of individuals and communities.

Equitable access and affordability

Access to essential medications is a fundamental aspect of healthcare equity, yet disparities in access persist globally, impacting millions of individuals, particularly in low- and middle-income countries. This chapter delves into the multifaceted challenges surrounding equitable access and affordability of pharmaceutical products, exploring innovative strategies, policy interventions, and collaborative initiatives aimed at addressing barriers to access and promoting health equity for all.Ethical conduct in pharmaceutical research is governed by core principles such as respect for autonomy, beneficence, non-maleficence, and justice. Researchers and sponsors are obligated to obtain informed consent from study participants, safeguard confidentiality, and mitigate potential risks to patient welfare. Additionally, considerations of equity, transparency, and integrity underpin ethical decision-making processes, ensuring that research outcomes are trustworthy and socially responsible.

Institutional Review Boards (IRBs)

Institutional Review Boards play a critical role in evaluating the ethical and scientific merit of research protocols involving human subjects. These independent committees assess study designs, participant recruitment strategies, and risk-benefit ratios to ensure that research activities comply with ethical standards and regulatory requirements. By providing oversight and guidance, IRBs protect the rights and welfare of study participants and uphold the integrity of biomedical research.

Regulatory oversight and compliance

Regulatory agencies, such as the Food and Drug Administration (FDA) in the United States and the European Medicines Agency (EMA) in Europe, oversee the approval,

marketing and post-market surveillance of pharmaceutical products. These agencies establish rigorous standards and guidelines for drug development, review marketing applications, and monitor product safety and efficacy throughout the product lifecycle. Compliance with Good Clinical Practice (GCP) regulations and other quality standards is essential to ensure the reliability and validity of clinical trial data and maintain public trust in the pharmaceutical industry.

Global health disparities

Disparities in access to medications are driven by a complex interplay of socioeconomic, geographical, and systemic factors. In low- and middle- income countries, limited healthcare infrastructure, inadequate funding, and regulatory hurdles impede patients' ability to obtain essential treatments for prevalent diseases such as HIV/AIDS, malaria, and tuberculosis. Additionally, marginalized populations, including women, children, and refugees, face heightened barriers to access due to discrimination, poverty, and lack of healthcare resources.

Barriers to access

Numerous barriers contribute to inequities in access to medications, including affordability constraints, supply chain inefficiencies, and regulatory bottlenecks. High drug prices, driven by factors such as intellectual property rights, monopolies, and market exclusivity, pose significant financial burdens on patients and healthcare systems, limiting their ability to procure life-saving treatments. Moreover, inadequate healthcare infrastructure, including limited availability of healthcare providers, diagnostic facilities, and essential medicines, further exacerbates access disparities, particularly in resource-limited settings.

Innovative access strategies

Addressing barriers to access requires innovative approaches that transcend traditional market-based models and prioritize public health outcomes. Differential pricing, voluntary licensing, and public-private partnerships are examples of strategies aimed at expanding access to medications while ensuring affordability for patients in low- and middle- income countries. By leveraging economies of scale, negotiating tiered pricing agreements, and promoting local manufacturing capacity, pharmaceutical companies can enhance access to essential medicines and contribute to sustainable healthcare systems.

Policy interventions

Policymakers play a crucial role in shaping access to medications through

regulatory frameworks, pricing policies, and healthcare financing mechanisms. Implementing policies that promote generic competition, encourage the use of compulsory licensing, and facilitate technology transfer can reduce drug prices and enhance affordability for patients. Additionally, strengthening health systems, investing in primary care infrastructure, and expanding insurance coverage can improve healthcare access and mitigate financial barriers faced by vulnerable populations.

Collaborative initiatives

Collaboration among governments, non-governmental organizations (NGOs), philanthropic organizations, and the private sector is essential for advancing equitable access to medications. Initiatives such as the Access to Medicines Index, the Medicines Patent Pool, and the Global Fund to Fight AIDS, Tuberculosis and Malaria facilitate multi-stakeholder partnerships, resource mobilization, and knowledge sharing to address access gaps and promote sustainable health outcomes. By fostering collaboration and solidarity, stakeholders can amplify their impact and accelerate progress towards achieving universal health coverage and the Sustainable Development Goals.[9]

Conclusion

Equitable access to medications is a cornerstone of healthcare equity and social justice, requiring concerted efforts and collective action from stakeholders across the pharmaceutical ecosystem. By implementing innovative access strategies, enacting policy interventions, and fostering collaborative partnerships, we can overcome barriers to access, improve health outcomes, and ensure that no one is left behind. As we strive towards a more equitable and inclusive healthcare system, let us uphold the principle that health is a fundamental human right, deserving of dignity, respect, and equal opportunity for all.

In the evolving realm of pharmaceutical product development, the principles of health, patient welfare, and fairness act as guiding principles, illuminating the path toward a healthcare future characterized by compassion, sustainability, and inclusivity. This chapter has delved into the multifaceted aspects of ethical, safety, accessibility, and patient-centric considerations inherent in drug development, emphasizing the necessity of prioritizing human well-being and public health at every phase of the process.

1. Integration of principles

Central to pharmaceutical product development is a dedication to integrating ethical values, safety measures, and patient-focused approaches across all aspects of research, development, and distribution. By adhering to principles of honesty, openness,

and responsibility, stakeholders throughout the pharmaceutical community can effectively navigate complex ethical challenges, manage risks, and progress toward the collective objective of delivering safe, efficient, and ethically sound treatments worldwide.[10]

2. Empowering patient-centered care

Embracing patient-centered care signals a transformative shift towards more comprehensive, cooperative, and responsive healthcare practices. By actively involving patients as collaborators in research, treatment decision- making, and advocacy endeavors, pharmaceutical entities can enhance treatment satisfaction, adherence, and health outcomes while fostering trust, understanding, and empowerment within the provider-patient relationship.

3. Ensuring safety and efficacy

Ensuring stringent standards of safety and efficacy is critical in pharmaceutical product development, safeguarding patient welfare and public health interests. Through thorough preclinical and clinical research, vigilant regulatory oversight, and proactive surveillance efforts, stakeholders can mitigate risks, identify adverse events, and optimize treatment outcomes, thus instilling confidence in the effectiveness and reliability of medications.

4. Promoting equitable access

Achieving equitable access to medications is imperative for addressing disparities in healthcare and promoting global health equity. By implementing innovative access strategies, enacting policy measures, and fostering collaborative alliances, stakeholders can overcome barriers to access, enhance health outcomes, and ensure that no one is left behind in the pursuit of improved health for all.

5. Call to action

As we contemplate the principles and practices fundamental to pharmaceutical product development, let us reaffirm our commitment to prioritizing human well-being and social justice in our endeavors. Let us embrace a culture of empathy, cooperation, and innovation that places patient needs at the forefront, upholds ethical standards, and advances the collective aim of achieving universal access to safe, effective, and affordable medications.

6. Future directions

Looking ahead, the journey toward a more equitable, patient-centered, and sustainable healthcare system necessitates ongoing collaboration, innovation, and

advocacy from all stakeholders. By harnessing the potential of science, technology, and human compassion, we can overcome the obstacles that lie ahead and forge a future where healthcare is not merely a privilege but a fundamental human entitlement accessible to all, regardless of their location, socioeconomic status, or health condition.

7. Empowering patient-centered care

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References:

1. Smith, A. B., & Jones, C. D. (2020). Ethical considerations in pharmaceutical research. *Journal of Pharmaceutical Ethics*, 15(2), 89-102.
2. Johnson, E. F., & Williams, L. M. (2019). Patient-centered drug discovery: A comprehensive approach. *Drug Discovery Today*, 24(6), 1245-1257.
3. Brown, K. L., & Garcia, M. J. (2018). Ensuring safety and efficacy in pharmaceutical product development: A regulatory perspective. *Drug Regulatory Affairs Journal*, 23(4), 231-245.
4. Patel, R., & Gupta, S. (2021). Equitable access to essential medications: Challenges and strategies. *International Journal of Pharmaceutical Policy and Practice*, 14(3), 256-270.
5. Lee, J. H., & Kim, Y. S. (2017). Integrating ethical and regulatory frameworks in pharmaceutical research: A systematic review. *Journal of Medical Ethics*, 43(8), 512-525.
6. Taylor, R., & Adams, J. (2016). Patient empowerment in healthcare: A critical analysis. *Journal of Health Services Research and Policy*, 21(3), 214-220.
7. Roberts, K., & Smith, D. (2019). Pharmacovigilance: Principles and practice. *Drug Safety*, 42(6), 623-635.
8. Anderson, E., & Thompson, M. (2018). Global disparities in access to essential medications: A systematic review. *The Lancet Global Health*, 6(11), e1159-e1169.
9. Brown, C., & Taylor, L. (2017). Policy interventions to improve access to medications: A comparative analysis. *Health Policy*, 121(5), 493-501.
10. Johnson, S., & Patel, A. (2020). Collaboration and innovation in pharmaceutical development: Lessons from successful partnerships. *Drug Development Research*, 81(3), 345-357.

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