CHAPTER 3

Proprioceptive Neuromuscular Facilitation

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Chapter Outline

Physical therapists evaluate and manage movement system disorders in order to promote optimal movement and functional recovery. Impairments, activity limitations, and participation restrictions are diagnosed and become the focus of treatment. This chapter focuses on the intervention concepts and techniques of ***Proprioceptive Neuromuscular Facilitation (PNF).***

History and Overview

The philosophy, principles, and techniques of this approach were initially developed by Dr. Herman Kabat, a neurophysiologist and physician, and Maggie Knott, a physical therapist, in the 1940s and early 1950s. Their early focus was on developing a hands-on treatment that could be used to facilitate and strengthen effective patterns of movement. Dorothy Voss, also a physical therapist, joined the team in 1952. Together, they refined the practice of PNF, enhancing its focus on promoting functional activities. Maggie Knott and Dorothy Voss authored the first PNF book, *Proprioceptive Neuromuscular Facilitation,* in 1956 as well as two subsequent editions appearing in 1968 and 1985.[1] Adler, Beckers, and Buck are the authors of a more recent comprehensive text, *PNF in Practice,* now in its fourth edition.[2]

Early on, Kabat and Knott established initial postgraduate training institutes, known as the Kaiser-Kabat Institutes. Currently, graduate training programs (3-, 6-, or 9-month) are offered at Kaiser Permanente in northern California. These programs include both didactic and laboratory instruction and supervised patient treatment. The 9-month course offers advanced course work and residency training with supervised teaching experiences.[3] PNF is currently offered in many countries as part of the physical therapy curriculum and in postgraduate training courses. In 1985 the International PNF

Instructor Group was formed, leading to the formation of the International PNF Association (IPNFA) in 1990. Its members consist of instructors and persons interested in PNF and in maintaining continuity and standards in PNF instruction, practice, and research. The objectives of the IPNFA and a full range of courses and levels of instruction can be found at their website (www.ipnfa.org).[4]

PNF has been successfully applied to a variety of patient populations undergoing rehabilitation across the lifespan and to a variety of conditions. Applications to neurological populations (e.g., stroke, multiple sclerosis, Parkinson's disease, incomplete spinal cord injury) include motor control training and synergistic patterns of movement, balance, and gait training. Applications to musculoskeletal populations (e.g., spinal, knee, and ankle injuries and restrictive disorders such as adhesive capsulitis and ankylosing spondylitis) include interventions to improve range of motion, strength, synergistic timing, and stability. Applications to cardiopulmonary populations include interventions to improve chest wall mobility and respiration. A summary of available research and the quality of the evidence is discussed in the final section of this chapter.

Key components of PNF include:

- Use of synergistic patterns of movement
- Use of techniques to facilitate and enhance coordinated muscle activity and strength
- Use of functional activities and postures to promote optimal recovery
- Use of motor learning and motor control principles to promote optimal movement.

Synergies represent an important organizational element of the central nervous system (CNS) that serve to stabilize performance variables.[5] With practice, synergistic performance improves. In PNF, the synergist patterns are rotational and diagonal in nature rather than straight plane movements. This is an important concept that mirrors normal movement. The overall goal is to facilitate proximal stability of the trunk for distal controlled mobility of the extremities and to improve voluntary control and coordination of muscles both within and among patterns. Extremity patterns are unilateral or bilateral, placing greater emphasis on the trunk and varying in difficulty when combined with functional activities and postures (e.g., hooklying, rolling, sitting, quadruped, kneeling, modified plantigrade, standing, and locomotion). Techniques, largely proprioceptive, are used to facilitate or enhance movement. Motor learning principles (e.g., practice, repetition, feedback) are incorporated to promote acquisition, retention, and transfer of learning of new motor skills.

PNF Principles and Basic Procedures

Principles and basic procedures inherent to PNF are used to optimize the patient's ability to move (summarized in Box 3.1). Overall goals include improved function with improved motor control, strength, and endurance. The therapist engages the patient through effective use of manual contacts, verbal commands, body position and body mechanics, and visual guidance of movement. Coordinated movement and timing are enhanced through the use of resistance, stretch, irradiation and reinforcement, and traction or approximation. Each patient has unique needs that determine the appropriate use and timing of these foundational elements. The therapist must recognize how and when to apply these elements and when to withdraw them to help the patient progress to independent movements. For weak or disordered movements, the effects of applying several elements during the same exercise (e.g., resistance, stretch, dynamic verbal commands) are additive and have a cumulative effect. Contraindications to the use of PNF include many of the same impediments to exercise in general, such as significant pain, unstable joints or fractures, and unstable medical condition.

BOX 3.1 PNF Principles and Basic Procedures

Body position:

Patient: Optimal patient performance is facilitated by ensuring that the patient is in optimal alignment. This includes positioning the patient in as close to neutral alignment as possible and providing support to body segments as needed. Muscle positioning at optimal range of function allows for maximal contractile response, and changing the patient's body position can emphasize certain segments of a pattern or alter postural stability demands.

Therapist: The therapist is positioned directly *in line* with the desired motion to optimize application of resistance. Effective positioning also reduces the work of the therapist's arms and hands by allowing the resistance to come from the therapist's own body weight during weight shifting.

Manual contacts: Precise hand placements are used to apply input over active muscles to guide movement, facilitate strength of contraction, and to provide resistance opposite the direction of movements. A *lumbrical grip* is used to provide a comfortable and secure grip and to optimize rotation resistance.

Verbal commands and cues: Verbal commands (VCs) must be clear and concise. They are focused on three areas: preparation (preparing the patient for movement), action (assisting the patient in the start and execution of the movement), and correction (assisting the patient how to modify the movement as needed).

Commands should be well-timed to the patient's movements and activity demands. Excessive or wordy cues are counterproductive and can impede motor learning.

Patterns of movement: Normal functional movements are composed of synergistic patterns involving the muscles of the limbs and trunk. Synergistic patterns of movement are the basis of PNF patterns.

Timing: Appropriate timing refers to the sequencing of muscle activity to ensure smooth, coordinated movement. Functional activities require proximal stability for distal mobility. In extremity patterns, normal timing is from distal to proximal.

Appropriate resistance: Appropriate resistance facilitates muscle contraction.[6] Resistance is applied manually to contracting muscles and functionally through the use of gravity to all types of contractions (isotonic and isometric). Appropriate resistance is used to allow for a smooth and coordinated contraction. It varies according to the individual patient and is adjusted to the goals of the specific activity.

Approximation: Approximation (joint compression of an extremity or the trunk) is used to facilitate muscle responses in extensor patterns or during stabilizing activities. It can be applied manually by compressing the joint surfaces or functionally through the use of anti-gravity postures during upright weight-bearing positions (e.g., sitting, standing, bouncing on a ball).

Traction: Traction (elongation of an extremity) is applied throughout the arc of motion and is used to facilitate muscle responses (pulling or mobilizing movements).

Visual input: The patient uses vision as a source of feedback to guide movements and enhance responses. The patient is instructed to look at the movements as they are occurring.

Irradiation and reinforcement: Irradiation and reinforcement is the overflow of neuronal excitation from stronger motor units to motor units that may be weaker or inhibited. The spread or expansion of muscle response from stronger muscles to weaker muscles can occur in any direction and across any segment in the body: ipsilateral, contralateral, from extremities to trunk, or from trunk to extremities.

Stretch: The elongated position (lengthened range) of muscle and the stretch reflex are used to initiate dynamic movements and facilitate existing contractions through increased motor unit recruitment. All synergistic muscles in the pattern are elongated to optimize the effects of initial stretch. Verbal cues should be synchronized with the stretch to enhance volitional responses, and resistance maximizes the effects of stretch.

Adapted from Voss et al.,[1] Adler et al.,[2] and Johnson and Saliba Johnson.[6]

Basic procedures for facilitation in PNF include patient position, therapist position, manual contacts, verbal cues and commands, patterns of movement, timing, resistance, approximation or traction, visual input, irradiation and reinforcement, and stretch.

Patient position is key to optimal patient performance and is facilitated by ensuring that the patient is in optimal alignment. This includes positioning the patient in as close to neutral alignment as possible and providing support to body segments as needed. Muscle positioning at optimal range of function allows for maximal contractile response *(length-tension relationship)*. The greatest muscle tension is generated in midranges; weak contractile force *(active insufficiency)* occurs in the shortened ranges. The lengthened range provides optimal stretch for muscle spindle support of contraction, whereas the shortened range with muscle-spindle unloading provides the least amount of muscle spindle support for contraction. Changing the patient's body position (e.g., supine, sitting, standing) can be used to emphasize certain segments of a pattern and to alter (increase or decrease) the postural stability demands.

Therapist position is important to optimize the application of resistance. The therapist is positioned directly *in line* with the desired motion, with the pelvis, shoulders, and lower extremities facing the direction of the movement. Effective therapist positioning also reduces the work of the therapist's arms and hands by allowing the resistance to come from the therapist's own body weight during weight shifting. In extremity patterns, as the limb moves through the pattern the therapist's position and angle of pull changes to continually optimize resistance.

Precise ***manual contacts*** (hand placements) are used to apply input over active muscles to guide movement, facilitate strength of contraction, and provide resistance opposite the direction of movements. The sensory input allows the patient to anticipate upcoming movement demands and to provide appropriate feedforward adjustments. A *lumbrical grip* is used to provide a comfortable and secure grip and to optimize rotation resistance. This consists of the therapist's hand positioned in metacarpophalangeal flexion with fingers and thumb gripping the opposite sides of the distal segment.

Verbal cues and commands must be clear, concise, and well-timed to the patient's movements and activity demands. Excessive or wordy cues are counterproductive and can impede motor learning.

- ***Preparatory Verbal Cues*** ready the patient for movement (what to do). They should optimally be accompanied by demonstration and/or guided movement to ensure the patient knows the idea behind the movement (cognitive stage of motor learning).

- ***Action Verbal Cues*** guide the patient through the movement, helping the patient learn how and when to move (associated stage of motor learning). *Dynamic action VCs* are used to enhance the strength of muscle responses and coordination of synergistic components (e.g., *"Pull up and across your face, now bend your elbow"*). *Soft action VCs* are used when relaxation is the goal (e.g., *"Move slowly back and forth"*). Timing is critical. The patient's actions must be carefully coordinated with the therapist's VCs, resistance, and manual contacts.
- ***Corrective Verbal Cues*** provide augmented feedback to help the patient modify movements.

Normal functional movements are composed of synergistic ***patterns of movement*** involving the muscles of the limbs and trunk. Patterns of movement are generated by the motor cortex with input from the basal ganglia and cerebellum for programming, timing, and coordination. Synergistic patterns of movement are the basis of PNF patterns.

Normal (appropriate) ***timing*** refers to the sequencing of muscle activity to ensure smooth, coordinated movement. Functional activities require proximal stability for distal mobility; thus, core stability of the trunk is a basic requirement, and sequencing of contractions occurs proximal to distal. In extremity patterns, normal timing is from distal to proximal. Distal segments (hand/wrist or foot/ankle) begin the movement, followed closely by rotation and then proximal components. Rotation continues smoothly throughout the pattern.

Appropriate resistance (optimal resistance) facilitates muscle contraction.[6] With appropriate resistance, both intrafusal and extrafusal muscle fibers contract, resulting in enhanced recruitment of motor units and improved strength of contraction. Resistance is applied manually to contracting muscles and functionally through the use of gravity to all types of contractions (isotonic [concentric and eccentric] and isometric). *Light resistance* applied to weak muscles is facilitatory and is usually applied in combination with light stretch. Appropriate resistance is used to allow for a smooth and coordinated contraction. It varies according to the individual patient and is adjusted to the goals of the specific activity. Resistance is also used to promote relaxation of antagonist muscles through the effects of reciprocal inhibition. It is important to monitor the patient for breath holding (commonly seen in isometric contractions), excessive fatigue, and unwanted irradiation.

Approximation (compression of the joints of an extremity or the spine) is used to facilitate muscle responses in extensor patterns or during stabilizing activities. It can be applied manually by compressing the joint surfaces or functionally through the use of gravity and body weight acting on the body during upright weight-bearing positions (e.g., sitting, standing, bouncing on a ball). Approximation is maintained throughout the pattern or activity and is combined with appropriate resistance and stabilizing VCs (e.g., *"Hold, hold"*). When using approximation, it is important to ensure that all joints, including the spine, are properly aligned. Indications for approximation include enhancing contraction of antigravity, stabilizing muscles and enhancing function in weight-bearing postures for stabilization control.

A ***traction*** force applied throughout the arc of motion is used to facilitate muscle responses. Traction is maintained throughout the pattern and combined with appropriate resistance and dynamic VCs (e.g., *"Pull up"*). Indications for traction include weakness and the inability of muscles to function in mobilizing patterns (e.g., open kinetic chain movement coupled with a stabilizing core response).

The patient uses ***vision*** as a source of feedback to guide movements and enhance responses. The patient is instructed to look at the movements as they are occurring. During extremity patterns, this includes instructing the patient to turn the head to visually follow the distal segment (e.g., hand) through to completion of the movement. A mirror can be used to provide visual input and assist with trunk alignment and movements of the head, trunk, and extremities.

Irradiation and reinforcement is the overflow of neuronal excitation from stronger motor units to motor units that may be weaker or inhibited.[7] The spread or expansion of muscle response from stronger muscles to weaker muscles can occur in any direction and across any segment in the body: ipsilateral, contralateral, from extremities to trunk, or from trunk to extremities. *Temporal summation* (resulting from an increase in the frequency of a stimulus over time) and *spatial summation* (resulting from a number of different stimuli being applied) can contribute to the spread of excitation and motor unit output across muscles. Appropriate resistance is the main mechanism for securing irradiation. Indications for the use of irradiation include to enhance strength of contraction and synergistic muscle activity.

Quick stretch can be used to facilitate muscle contraction. The elongated position (lengthened range) of muscle and the stretch reflex are used to initiate dynamic movements and facilitate existing contractions through increased motor unit recruitment. All synergistic muscles in the pattern are elongated to optimize the effects of initial stretch. Verbal cues for voluntary movement must be synchronized with the stretch to enhance volitional responses. Resistance applied to the contracting muscle maximizes the effects of stretch.

PNF Techniques

Central to PNF are a group of therapeutic *techniques* designed to promote and enhance movement. These techniques are presented in Box 3.2 and include rhythmic initiation, reversals of antagonists, rhythmic stabilization, repeated stretch, combination of isotonics, timing for emphasis, contract-relax, hold-relax, and replication.

Rhythmic initiation is used to promote learning of a new movement, improve intra- and intermuscular coordination, and promote relaxation and independent movement. In rhythmic initiation, movement training occurs in four phases. First, the patient is instructed to relax (*"Relax, let me move you"*). The therapist moves the patient passively through the range, establishing appropriate speed and rhythm using verbal commands. Second, movements are then progressed to active assisted (*"Now, help me move you"*). Third, the patient is then asked to move independently (*"Now, move up on your own"*). Finally, in the fourth phase, movements are resisted (*"Now, push up"*). Appropriate resistance is used during the resistive phase to enhance movement.[4] Transitions between the different phases are smooth and continuous. Rhythmic initiation typically involves unidirectional movement but can be applied in both directions to enhance reciprocal movements. Indications for using rhythmic initiation include an inability to relax, hypertonicity (e.g., spasticity and rigidity), difficulty initiating movement, uncoordinated movement, motor planning or motor learning deficits (e.g., apraxia or dyspraxia), or communication deficits (e.g., aphasia).

Reversals of antagonists include two techniques, ***dynamic reversals*** and ***stabilizing reversals,*** which allow for agonist contraction followed by antagonist contraction without pause or relaxation. Dynamic reversals, also known as isotonic reversals, use isotonic concentric contractions of first agonists, then antagonists performed against resistance. First, the therapist resists contraction of one pattern (e.g., flexion-adduction-external rotation: *"Now, pull up and across your body"*). At the end of the desired range, a preparatory command is given to reverse direction, and the therapist switches hands to resist the opposite pattern. The patient is then instructed to move in the opposite direction (e.g., action command for extension-abduction-internal rotation: *"Now, push down and out toward me"*). The technique can be used with or without a hold at the end range of each direction. Reversals are repeated as often as necessary. If an imbalance exists, the stronger pattern is selected first, with progression to the weaker pattern. Modifications include working in a particular part of the range, progressing to movement through increments of range of motion (ROM) to full range of motion. Initially, the patient can be asked to hold steady at the endpoint of ROM in preparation for the transition (dynamic reversals, hold): *"Now, pull up and across your body and hold."* Progression is then to no hold as the patient learns to transition smoothly between patterns. An initial stretch can be used to initiate the movement response. General goals of dynamic reversal are to improve intra- and intermuscular coordination (smooth reversals of antagonists, rate of movement), strength, active range of motion, and endurance. This technique may be indicated for patients with impaired strength, range, and coordination; inability to easily reverse directions between agonist and antagonists; or fatigue.

BOX 3.2 PNF Techniques

Rhythmic Initiation
Used to promote learning of a new movement, improve coordination, and promote relaxation and independent movement. Movement training occurs in four phases: (1) passive movement through the range, (2) active assisted movement, (3) independent movement, and (4) resisted movement.

Reversals of Antagonists
Two techniques that allow for agonist contraction followed by antagonist contraction without pause or relaxation are *dynamic reversals* and *stabilizing reversals.*

Dynamic Reversals (Isotonic Reversals)
Dynamic reversals use isotonic concentric contractions of first agonists, then antagonists performed against resistance. First, the therapist resists contraction of one pattern; at the end of the desired range, the therapist switches hands to resist the opposite pattern, and the patient is instructed to move in the opposite direction.

Stabilizing Reversals (Isotonic Reversals)
Stabilizing reversals use alternating contractions progressing to stabilizing holds of first agonists and then antagonists against resistance. A low load resistance is applied very slowly to a particular body part, and then the therapist builds the resistance until a strong stabilizing hold is felt as the patient is able to maintain the position; the therapist then transitions hands to placement in the opposite pattern, and the patient resists the opposite direction with a strong stabilizing hold; very little motion is allowed.

Rhythmic Stabilization (Isometric Reversals)
Rhythmic stabilization uses isometric contractions of antagonist patterns, focusing on cocontraction of muscles. Rhythmic stabilization of the trunk utilizes resistance applied to one segment while applying resistance to the other segment. The therapist builds the resistance up slowly; no movement is allowed.

Repeated Stretch (Repeated Contractions)
Repeated isotonic contractions are performed, directed to the agonist muscles, initiated by a quick stretch, and enhanced by resistance. The stretch can be performed from the beginning of the range (lengthened

range) for very weak muscles or throughout the range at a point of weakness.

Combination of Isotonics

Combination of isotonics uses concentric, isometric, and eccentric contractions of agonist muscles without loss of tension.[6] The limb is resisted moving through the range (concentric contraction), followed by a stabilizing contraction (holding in the position) and then an eccentric or lengthening contraction, moving slowly back to the start position; there is no relaxation between the types of contractions.

Timing for Emphasis

Timing for emphasis alters normal timing using resistance to enhance a more localized contraction and to emphasize a component within the pattern. For example, appropriate resistance can be used to elicit a strong contraction and allow irradiation and reinforcement to occur from strong to weak muscles within a synergistic pattern.

Contract-Relax

This facilitation stretching technique is usually performed at a point of limitation of ROM. The patient actively moves the limb in the pattern to the point of limitation using agonist contraction; the therapist then asks for a strong contraction of the range-restricting muscles (antagonists). The contraction is held for 5 to 8 seconds, enhancing relaxation through the inhibitory effects from autogenic inhibition. Voluntary relaxation and active movement then follow the hold into the new range of the agonist pattern. This action enhances relaxation through the additional inhibitory effects of reciprocal inhibition.

Hold-Relax

This facilitation stretching technique is usually performed in a position of comfort and below the level that causes pain. The patient actively moves the limb in the pattern to the end of pain-free ROM (agonist contraction). A strong isometric contraction of the restricting muscles (antagonists) is resisted, followed by voluntary relaxation and passive movement into the newly gained range of the agonist pattern.

Replication (Hold-Relax-Active Motion)

The patient is positioned in the end position (shortened range) of a movement and is told *"Hold, and don't let me move you."* The isometric contraction is resisted, followed by voluntary relaxation and passive movement into the lengthened range *("Relax. Now let me move you back").* The therapist then instructs the patient to perform an isotonic contraction through the range: *"Now, push back"* into the end position again. Stretch and resistance are applied to facilitate the isotonic contraction. For each repetition, increasing ROM is desired.

Adapted from Voss et al.,[1] Adler et al.,[2] and Johnson and Saliba Johnson.[6]

Stabilizing reversals, also known as isotonic reversals, use alternating contractions with minimal movement (slow reversals) progressing to smaller ranges and finally to stabilizing holds of first agonists *("Hold this position, and don't let me move you. Hold it.")* and then antagonists *("Now hold this position, and don't let me move you")* against resistance. A low load resistance is applied very slowly to a particular body part or two separate body segments. The therapist builds the resistance (combined with traction or approximation) until a strong stabilizing hold is felt under both hands, indicating that the patient is able to stabilize and maintain the position. Once a stabilizing contraction is achieved, one of the therapist's hands should begin increasing the amount of resistance with the intention to slowly take over application of resistance (control of contraction) to free the opposite hand. Throughout this transition, the verbal command continues to be *"Hold it; keep it there."* As one manual contact takes over, the opposite hand is "melting" off. Before the therapist's hands are transitioned to placement in the opposite pattern, a preparatory command is given. This sequence is repeated, with the therapist's hands moving from one body segment to the opposite body segment. If an imbalance exists, the stronger pattern is selected first, with progression to the weaker pattern. General goals of stabilizing reversals are to facilitate stabilizing contractions at the segment being resisted and improve stability, strength, intra- and intermuscular coordination, endurance, or range of motion. Stabilizing reversals may be indicated for patients with impaired strength, stability, balance, and coordination.

Rhythmic stabilization uses isometric contractions of antagonist patterns, focusing on cocontraction of muscles. In standing, rhythmic stabilization of the trunk utilizes resistance applied to one segment (e.g., on the anterior shoulder, the therapist's right hand pushes backward) while applying resistance to the opposite side pelvic segment (e.g., on posterior pelvis, the therapist's left hand pulls forward). The therapist builds the resistance up slowly and no movement is allowed. Verbal commands include *"Hold, don't let me move you, hold, hold."* The therapist then shifts hands and applies resistance in the opposite direction, keeping each hand on the same section of the trunk (e.g., the therapist's right hand is placed forward on the front of the shoulder and resists the hold while the left hand is placed on the back of the pelvis and resists the hold). Verbal commands include *"Now, don't let me move you the other way, hold, hold."* An alternative command is

"Don't let me twist you, hold, hold." Upper trunk flexors and rotators are resisted at the same time as lower trunk extensors and rotators. In sitting, upper trunk flexors and rotators on one side are resisted at the same time as upper trunk extensors and rotators on the opposite side. General goals of rhythmic stabilization are to improve stability (cocontraction of antagonists), strength, endurance, ROM, and intra- and intermuscular coordination; promote relaxation; and decrease pain. Indications for rhythmic stabilization include impaired strength and coordination, limitations in ROM, impaired stabilization control, and decreased balance.

Repeated stretch, also known as repeated contractions, are repeated isotonic contractions directed to the agonist muscles, initiated by a quick stretch and enhanced by resistance. The stretch can be performed from the beginning of the range (lengthened range) for very weak muscles or throughout the range at a point of weakness. The therapist gives a preparatory command *("Now")* while providing quick stretch of the muscles working in the pattern. An action command *("Pull up and across")* follows. The technique is repeated when the therapist notes a weakening of the contraction during a pattern *("Again, pull up and across")*. Sufficient opportunity for a volitional effort/muscular response must be allowed before the next repeated stretch. General goals of repeated stretch include enhancing initiation of motion and motor learning, increasing agonist strength and endurance, improving intra- and intermuscular coordination and ROM, and reducing fatigue. Indications for the use of repeated stretch may include impaired strength, difficulty initiating movement, fatigue, and limitations in active ROM. This technique should not be applied in the presence of joint instability, pain, or injured muscle.

Combination of isotonics uses concentric, isometric, and eccentric contractions of agonist muscles without loss of tension.[6] The limb is resisted, moving through the range (concentric contraction), followed by a stabilizing contraction (holding in the position) and then an eccentric or lengthening contraction, moving slowly back to the start position; there is no relaxation between the types of contractions. Verbal commands are directed toward each phase of the movement *("Push up." "Now, hold." "Now, slowly let me win." or "Slowly let it lengthen")*. The technique is typically used in antigravity activities and assumption of postures (e.g., bridging and sit-to-stand transitions). During rolling, combination of isotonics can initially begin with an isometric hold (in sidelying), then progress to an eccentric lengthening followed by concentric shortening, with the sequence repeated through increments in ROM. General goals of combination of isotonics are to improve motor learning and improve intra- and intermuscular coordination; increase strength and ROM; promote stability, eccentric control, and endurance; and improve function. Indications to use combination of isotonics include weak postural muscles, and the inability to eccentrically control body weight during movement transitions (e.g., sit-to-stand and stand-to-sit).

Timing for emphasis alters the normal timing of a pattern using resistance to enhance a more localized contraction and to emphasize a particular component within the pattern. For example, appropriate resistance can be used to elicit a strong contraction and allow irradiation and reinforcement to occur from strong to weak muscles within a synergistic pattern. The strong muscles can also be resisted isometrically ("locking in") while motion is allowed in the weaker muscles. Indications for the use of timing for emphasis include weakness, poor coordination, or both.

Contract-relax (CR) is a facilitation stretching technique that is usually performed at a point of limitation of ROM. The patient actively moves the limb in the pattern to the point of limitation using agonist contraction *("Pull your foot up, turn your leg out, and lift up and out")*. The therapist then asks for a strong contraction of the range-restricting muscles (antagonists) *("Now, turn your leg in and hold")*. The contraction is held for 5 to 8 seconds, enhancing relaxation through the inhibitory effects from autogenic inhibition. Voluntary relaxation and active movement then follow the hold into the new range of the agonist pattern *("Relax. Now turn and lift your leg up and out")*. This action enhances relaxation through the additional inhibitory effects of reciprocal inhibition. The cycle is typically repeated several times until no additional range is obtained. The technique is best followed with active movements in the new range (e.g., repeated contractions of the agonist muscles) to maintain or enhance gains in range.

General goals of contract-relax are to improve ROM through facilitation, inhibition, and strengthening and relaxation of muscle groups. Indications for use of contract-relax are limitations in ROM. Contraindications include recent injury with inflammation and swelling or recent surgery.

Hold-relax (HR) is a facilitation stretching technique that is usually performed in a position of comfort and below the level that causes pain. The patient actively moves the limb in the pattern to the end of pain-free ROM (agonist contraction). A strong isometric contraction of the restricting muscles (antagonists) is resisted (providing autogenic inhibition), followed by voluntary relaxation and passive movement into the newly gained range of the agonist pattern. The therapist instructs the patient to pattern: *"Hold, don't let me move you."* This is followed by a command to *"Relax; now, let me move your leg up and out."* General goals of hold-relax are to improve ROM through facilitating, inhibiting, strengthening, and relaxing muscle groups. Indications for use include limitations in passive ROM, especially with pain. Contraindications include recent injury with inflammation and swelling, or recent surgery.

Replication (Hold-Relax-Active Motion) is a facilitation stretching technique that is performed with the patient positioned in the end position (shortened range) of a movement and is told *"Hold, and don't let me move you."* The isometric contraction is resisted, followed by voluntary relaxation and passive movement into the lengthened range

("Relax, now let me move you back"). The therapist then instructs the patient to perform an isotonic contraction through the range *("Now, push back")* into the end position again. Stretch and tracking resistance are applied to facilitate the isotonic contraction. For each repetition, increasing ROM is desired. The goals of replication are to improve intra- and intermuscular coordination and agonist muscle control in the shortened range and promote motor learning. Indications for replication include marked weakness and inability to sustain a contraction in the shortened range.

Clinical Note: Combination of isotonics may be a more effective way to teach a new pattern. It is similar to replication, but instead of a passive movement into the range, the patient is taken there through an eccentric contraction. This allows for continued kinesthetic/proprioceptive awareness of the movement.

Applying the Principles to the Movement Patterns

The principles of PNF should guide the therapist's every manual interaction with a patient. Once a movement or stabilizing posture has been identified as the goal of treatment, the therapist should select the appropriate movement pattern to execute and techniques to utilize. The patterns should always be executed in the following manner:

- Position the patient appropriately.
- Assume an appropriate therapist position with proper body mechanics.
- Passively position the body part or segment to be facilitated in proper alignment.
- Determine the proper manual contact.
- Determine whether the intervention is to be passive, active-assisted, or resisted.
- If a resisted movement is desired, determine whether the patient's pattern is to be resisted in midrange or at lengthened range.
- If a stretch stimulus is to be used, ensure that the patient's segment is properly elongated.
- If a stretch stimulus is to be used, couple the quick elongation with the proper verbal command and appropriate resistance, being sure to emphasize the traction at the beginning of the range and throughout the movement.
- If a midrange position is selected to initiate resistance, begin with a slowly building isometric resistance and progress to either concentric or eccentric resistance.
- Always observe the whole patient to determine the effect of therapist resistance and ensure proper irradiation and reinforcement.
- Always ensure that the trunk and interconnecting joints demonstrate appropriate stability before facilitating an extremity pattern.[6]

PNF Patterns of Movement

Normal motor activity occurs in synergistic and functional patterns of movement. Proprioceptive neuromuscular facilitation patterns are *spiral* and *diagonal* in character and combine motion in all three planes: flexion/extension, abduction/adduction, and transverse rotation. They closely resemble patterns used in normal activities and sports. Patterns are varied by changing the action of the intermediate joint (i.e., elbow or knee) or by changing the position of the patient (e.g., supine, sitting, or standing). Patterns can be unilateral or bilateral; bilateral patterns can be symmetrical, asymmetrical, or reciprocal. Motion components and primary synergistic muscle components of the PNF patterns of movement are presented in Table 3.1 for the upper extremity (UE), in Table 3.2 for the lower extremity (LE), in Table 3.3 for the head and neck, and in Table 3.4 for the trunk.

Scapular Patterns

Patterns involving the scapula influence the function of the cervical and thoracic spine and the upper extremities. Both scapular motion and stability are required. Motion occurs in two diagonals: anterior elevation–posterior depression and posterior elevation–anterior depression. Patterns are typically performed in the sidelying position, although the sitting position may also be used. See additional discussion of scapular patterns in Chapter 4: Interventions to Improve Bed Mobility and Early Trunk Control.

Clinical Note: Scapular patterns contribute to the stabilization and motion of the upper extremities and to the function of the cervical and thoracic spine. Functional activities that require adequate motion and stability of the scapula include rolling, reaching, dressing, and UE weight-bearing.

Scapular Anterior Elevation—Posterior Depression

Position: The patient is positioned in sidelying (midfrontal plane) with the head in neutral; the therapist is positioned behind the patient in line with the movement (see Chapter 4: Interventions to Improve Bed Mobility and Early Trunk Control, Fig. 4.16).

Anterior Elevation

Start: The scapula and glenohumeral complex is down and back in posterior depression.
Movement: The scapula and glenohumeral complex moves up and forward toward the nose, with the inferior angle rotating away from the spine.
Verbal cues: *"Pull your shoulder up and forward. Pull."*
Manual contacts: One hand is placed on the superior/anterior aspect of the glenohumeral complex, and the other hand is placed over the first hand. Resistance is down and back.

Posterior Depression

Start: The scapula and glenohumeral complex is up and forward in anterior elevation.
Movement: The scapula and glenohumeral complex moves down and back, with the inferior angle rotating toward the spine.
Verbal cues: *"Push your shoulder down and back to me. Push."*
Manual contacts: The base (heel) of the hand is placed on the vertebral border of the scapula and lumbrical grip to control the inferior medial border of the scapula, and the other hand is placed over the first hand. Resistance is up and forward.

Clinical Note: Anterior elevation is used during rolling forward and forward reach; posterior depression is used during rolling backward, push-ups, and walking with crutches.[2]

Scapular Posterior Elevation—Anterior Depression

Position: The patient is positioned in sidelying; the therapist is positioned above and behind the patient's head in line with the movement.

Posterior Elevation

Start: The scapula and glenohumeral complex is positioned down and forward toward the opposite hip in anterior depression.
Movement: The scapula and glenohumeral complex moves up and back.
Verbal cues: *"Push your shoulder up and back. Push."*
Manual contacts: One hand is placed on the superior/posterior aspect of the acromion and the spine of the scapula, and the other hand is placed on top. Resistance is down and forward during the last half of the arc of movement.

Anterior Depression

Start: The scapula and glenohumeral complex is positioned up and backward in posterior elevation.
Movement: The scapula and glenohumeral complex moves down and forward toward the opposite hip.
Verbal cues: *"Pull your shoulder down toward your belly button. Pull."*

Manual cues: One hand is placed posteriorly on the axillary border of the scapula, and the other hand is placed on the lateral border of the pectoralis major muscle and inferior border of the coracoid process. Resistance is up and back.

Clinical Note: Posterior elevation is used when reaching backward while throwing and overhead dressing activities (putting on a shirt); anterior depression is used during forward throwing a ball, and reaching forward and down to the feet.[2]

Upper Extremity Patterns

Upper extremity patterns are named for the action occurring at the proximal joint (shoulder). There are two diagonal planes of motion.

- Diagonal 1 includes the antagonist pair of patterns flexion-adduction-external rotation (D1F) and extension-abduction-internal rotation (D1E).
- Diagonal 2 includes the antagonist pair of patterns flexion-abduction-external rotation (D2F) and extension-adduction-internal rotation (D2E).

The intermediate joint (elbow) can be maintained in extension (straight arm pattern) or can flex or extend using intermediate pivot action. See Table 3.1 for synergistic motion components. The terms *proximal hand* and *distal hand* refer to the location of the therapist's hand placement on the patient (manual contacts). The therapist's distal hand grips the patient's hand (palmar or dorsal surface); the proximal hand grips the patient's upper arm for emphasis of the shoulder or over the forearm for emphasis of distal joints. UE patterns are typically practiced in supine or sitting positions but can also be practiced in sidelying, prone on elbows, quadruped, or kneeling positions.